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DIOXINS AND FURANS IN BOTTOM SEDIMENTS NEAR THE 47 CANADIAN PULP AND PAPER MILLS USING CHLORINE BLEACHING

L. TRUDEL

MARCH 1991

WATER QUALITY BRANCH
INLAND WATERS DIRECTORATE
ENVIRONMENT CANADA
OTTAWA, ONTARIO

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EXECUTIVE SUMMARY

In 1988, concerns about dioxins and furans near chlorine-bleached pulp mills led Environment Canada to establish a national dioxin sampling program. Part of this program included a sampling survey and report on dioxins and furans in river and ocean bottom mud or sediments. The sampling was carried out in cooperation with provincial environmental agencies.

This report describes the contamination of sediments near pulp mills by dioxins and furans as a result of the national survey.

A total of 165 sediment samples were collected near the 47 chlorine-bleached pulp mills across Canada, 12 of which were in a coastal environment, and 35 of which were inland on river systems. Four other mills were sampled to act as a control.

Samples were analyzed by Environment Canada laboratories, and private contract laboratories for dioxins, furans, organic carbon, and the size of particles. A quality assurance/quality control (QA/QC) program was implemented to check for reliability and comparability of the data.

Contaminated samples from each site were evaluated by a contamination classification system based on Toxicity Equivalents (TEQ) of the most toxic member of the dioxin family, namely, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-T_4CDD). TEQ is a measure of total dioxins and furans based on the most toxic member, 2,3,7,8-T_4CDD. TEQ calculation may have led to overestimated results.

This classification system is not based on a demonstrated toxicity level or hazard assessment, as there are currently no sediment quality guidelines or criteria for sediment contamination by which the significance of sediment contamination could be judged. In the absence of such criteria, both a mathematical and a statistical approach were applied to the data.

Conclusions:

1) Dioxins or furans were detected in sediments below 95% of the mills in both inland and coastal locations.

2) Concentrations of 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-T_4CDF) ranging from 10 to 3,179 parts per trillion (pg/g) were measured at 70% of the mills.

3) 2,3,7,8-T_4CDD was detected in sediments at 25% of the mills. Sediments near five mills showed concentrations from 17 to 67 pg/g, while eight mills fell into the 2-15 pg/g range. The QA/QC data suggest a low level of confidence in results at these levels of concentration.

   There are no standards for dioxin and furan in sediments. Sediment results tend to support results obtained in fish and shellfish surveys.

4) Sediment data from this study show that British Columbia coastal mill sediments have a much higher degree of contamination, and a more complex mixture of dioxins and furans than those in inland mill sediments.

   Sediment data also show that six out of 10 British Columbia coastal mills have very high or high levels of sediment contamination.

   Out of a total of 35 inland mills sampled, 10 were found to have very high or high levels of sediment contamination. These 10 mills are located in British Columbia (4), Ontario (5), and in Quebec (1).

   Prairie mills, along with those in New Brunswick and Nova Scotia, and other Quebec mills, did not show high levels of sediment contamination.

5) While the results provide useful information on dioxins and furans in bottom sediments, they do not permit a definitive evaluation of the level of contamination for each site. Additional sampling at 16 of the 47 sites already tested is recommended to complete the study's data.

   The highest levels of regional contamination observed in Ontario and British Columbia sediments may reflect the more rigorous sampling program. In the other regions the less intensive survey carried out do not eliminate the possibilities of high values in those locations.

Recommended Survey Design Modifications:

Modifications are recommended to reduce factors which have hindered interpretation of the survey results.

Modifications recommended include: more specific QA/QC measures to enhance follow-up and detection limits and to determine the confidence level in the analytical results; more sampling where lack of samples or sediment characteristics prevented meaningful conclusions; changes to the sampling site selection strategy; as well as additional analyses of the most toxic congeners, the 2,3,7,8-substituted dioxins and furans.

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ABSTRACT

Environment Canada, with assistance from provincial agencies, has conducted a sediment sampling program to determine dioxin and furan levels in the vicinity of the 47 Canadian pulp and mills using chlorine bleaching. The results of the program are described in this report.

Sediment samples collected over the study period were analyzed for dioxins and furans, organic carbon content and particle size distribution. Sediment samples were found to be contaminated by at least one form of dioxin or furan at most of the mill sites sampled. At several sites the level of contamination was high. In general, sediment samples from British Columbia coastal mill sites show higher levels and a more complex mixture of dioxins and furans than inland mill samples.

The report recommends changes to the survey design and additional sampling to complete the study's data and permit a definitive evaluation of the level of contamination for each site.

RÉSUMÉ

En collaboration avec des organismes provinciaux, Environment Canada a réalisé un programme d'échantillonnage des sédiments pour déterminer le niveau de contamination par les dioxines et les furanes à proximité des 47 usines canadiennes de pâtes et papiers utilisant le blanchiment au chlore. Les résultats du programme sont décrits dans ce rapport.

Les échantillons de sédiments prélevés au cours de la période d'étude ont été analysés pour en déterminer la teneur en dioxines, en furanes et en carbone organique et pour en préciser la distribution granulométrique. Le programme a permis d'établir un niveau élevé de contamination à plusieurs lieux d'échantillonnage et de détecter la présence d'au moins une forme de dioxine ou de furane dans les sédiments à la plupart des lieux. En général, les sédiments prélevés près des usines le long de la côte de la Colombie-Britannique sont plus contaminés et contiennent un mélange de dioxines et de furanes beaucoup plus complexe que ceux prélevés à proximité des usines installées le long de cours d'eau intérieurs.

Il est recommandé d'apporter des modifications à la conception de l'étude et d'effectuer des échantillonnages supplémentaires pour compléter les données de l'étude et tirer des conclusions définitives au sujet du niveau de contamination à chaque lieu d'échantillonnage.

1.0 INTRODUCTION

Within the last five years evidence has been mounting that effluents from pulp and paper mills which use chlorine in their bleaching processes contain highly toxic chlorinated dioxins and furans (Rappe et al., 1989; Clement et al., 1989; Elliot et al.,1988; Amendola et al., 1989). This has resulted in increased public concern throughout the country and the request for stricter government controls on pulp mill discharges.

The discovery of polychlorinated dibenzo-para-dioxins and dibenzofurans in aquatic environments near several mills using chlorine in their bleaching process led to the establishment of a national dioxin sampling program in 1988. The objectives of the program were to determine the extent and degree of dioxin and furan contamination, and to provide the basis for appropriate action to protect the environment and human health.

The dioxin sampling program consisted of three major elements:

i) dioxins/furans in fish and shellfish sampled in the vicinity of the 47 mills using chlorine bleaching;

ii) dioxins/furans in bottom sediments collected in the vicinity of the mills;

iii) dioxins/furans in effluents of the mills in question.

The sampling program involved the collaboration of three federal departments, Fisheries and Oceans, Environment, and Health and Welfare, in cooperation with provincial agencies and the pulp and paper industry.

The dioxins-in-sediments program component was conducted by Environment Canada with the assistance of several provincial agencies. It focused on the provision of information on the presence of dioxin and furan contamination of sediments in the vicinity of the mills and to shed some light on the pathway of dioxins from sediments into biota. The detailed results of this program component are reported in this document. Information from the fish and effluent program components are used in the discussion of this document.

2.0 SAMPLING LOCATIONS

Figure 1 shows the location of the 47 Canadian pulp and paper mills using chlorine bleaching. Table 1 lists the mills included in this study. Appendix A includes maps of mill locations for each region, and a detailed description and illustration of the bottom sediment sampling sites at each mill. The mills selected for this study are located along lakes, streams, rivers, bays and estuaries. The receiving waters are of a diversity of conditions (fresh, brackish and salt water, lentic and lotic systems, various rates of flow, tidal influence, etc.,) with a profound influence on the effluent mixing and sediment dispersion (sedimentation). Specific sampling site locations were selected according to characteristics of each milieu to be sampled. The collection of bottom sediments in the vicinity of inland mills was carried out in two areas: downstream at sites influenced by the effluent plume; and, when possible, upstream above the influence of the mill effluent discharge.

Accessibility, convenience and practicability were factors that intervened in the sampling sites selection. Consequently sampling locations vary widely, from close to the discharge point to a few kilometers upstream and downstream according to local conditions. During upstream (background) site selection, care was taken to ensure that the location was free of local contamination such as wood treatment facilities using chlorophenols or the influence of other upstream pulp mills. No upstream samples were collected for mills in Quebec.

In the cases of coastal locations, upstream and downstream were not differentiated due to the potential influence of current patterns in the vicinity of the effluent discharge.

When looking for toxic organic chemicals in bottom sediment, it is well known that fine particle size (clay fraction instead of sand or gravel) samples should be collected as pollutants are more likely to be absorbed onto these particles (Horowitz, 1985; Allan, 1985; Sly, 1982). Although this approach places a bias on sampling site selection and does not permit the design of a uniform sampling program (since sedimentation zones vary from place to place), the adherence to this criterion was encouraged (Arsenault and Howell, 1987; Gaskin 1988). The high cost of analysis and the restricted number of samples to be submitted influenced the sampling allocation.

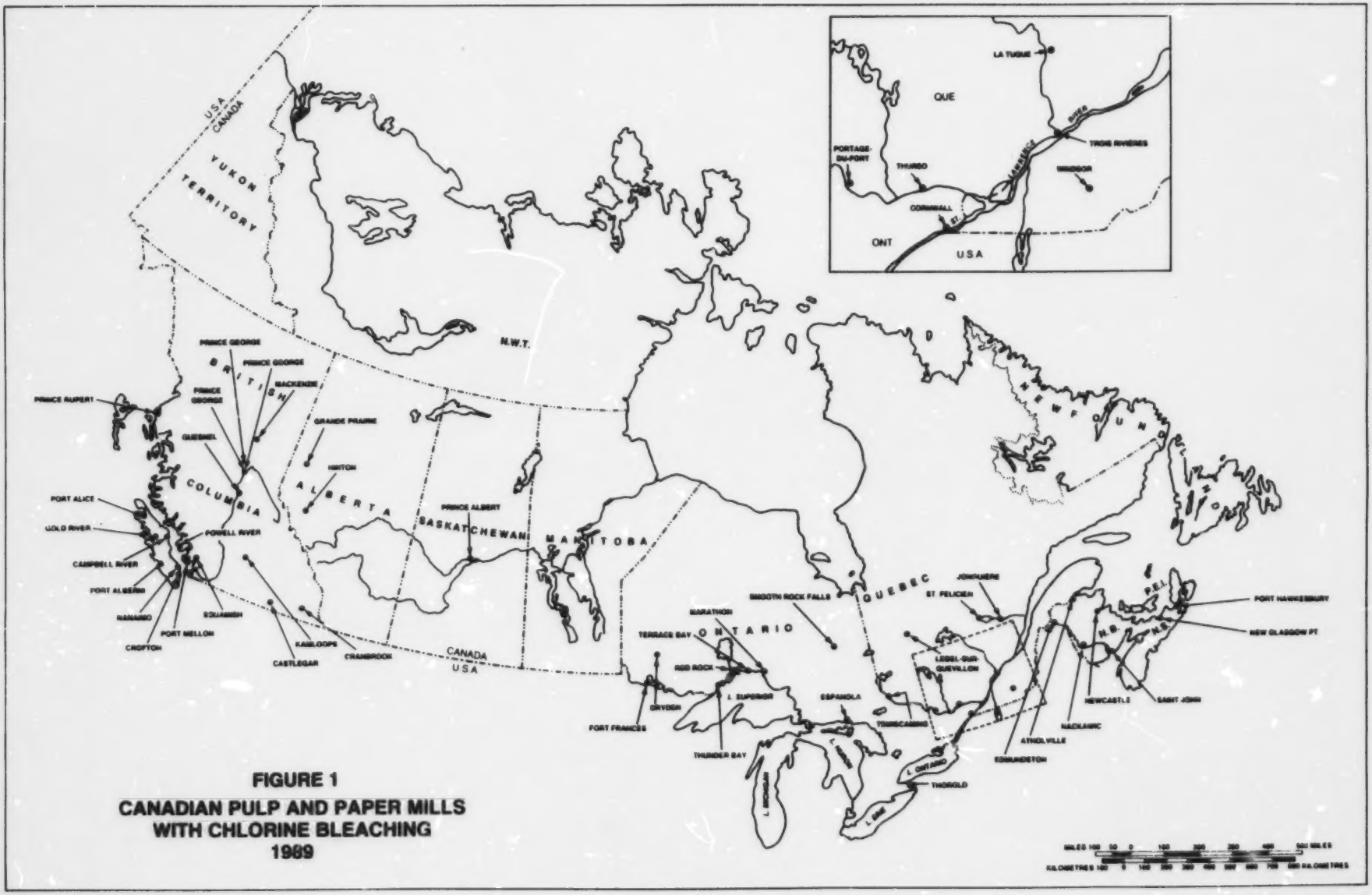

USA
CANADA
YUKON TERRITORY
N.W.T.
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
P.E.I.
N.S.
N.B.
PRINCE GEORGE
PRINCE RUPERT
QUESNEL
PRINCE GEORGE
MACKENZIE
GRANDE PRAIRIE
HINTON
PRINCE ALBERT
PORT ALICE
GOLD RIVER
CAMPBELL RIVER
PORT ALBERNI
NANAIMO
CROFTON
PORT MELLON
POWELL RIVER
SQUAMISH
KAMLOOPS
CASTLEGAR
CRANBROOK
CANADA
USA
MARATHON
TERRACE BAY
RED ROCK
DRYDEN
FORT FRANCES
THUNDER BAY
L. SUPERIOR
L. MICHIGAN
L. HURON
L. ONTARIO
L. ERIE
ESPANOLA
TIMMINS
HEARST
GOGAMA
GERALDTON
MISSION
MISSION
MISSION

TABLE 1

LIST OF MILLS USING CHLORINE BLEACHING AND CONTROL MILLS

DOE NO.	MILL	CITY	PROVINCE	COASTAL – C ISLAND – I
1.	Fletcher Challenge Canada Ltd. (Elk Falls Div.)	Campbell River	British Columbia	C
2.	Fletcher Challenge Canada Ltd. (Crofton Div.)	Crofton	B.C.	C
3.	C.P. Forest Products Ltd.	Gold River	B.C.	C
4.	Weyerhaeuser Canada Ltd.	Kamloops	B.C.	I
5.	Eurocan Pulp & Paper Ltd.*	Kitimat	B.C.	I
6.	Fletcher Challenge Canada Ltd.	Mackenzie	B.C.	I
7.	MacMillan Bloedel Ltd. (Harmac Div)	Nanaimo	B.C.	C
8.	MacMillan Bloedel Ltd. (Alberni Div.)	Port Alberni	B.C.	C
9.	Canfor Products Ltd. (Howe Sound)	Port Mellon	B.C.	C
10.	MacMillan Bloedel Ltd. (Powell River Div.)	Powell River	B.C.	C
11.	Northwood Pulp & Timber Ltd.	Prince George	B.C.	I
12/13	Canfor Prince George Pulp & Paper and Prince George Pulp & Intercontinental Pulp Ltd.	Prince George	B.C.	I
14.	Skeena Cellulose Inc.	Prince Rupert	B.C.	C
15.	Cariboo Pulp & Paper Company	Quesnel	B.C.	I
16.	Crestbrook Forest Industries Ltd.	Cranbrook	B.C.	I
17.	Western Pulp Partnership Ltd. (Woodfibre)	Squamish	B.C.	C
18.	Finlay Forest Industries Ltd.*	Mackenzie	B.C.	I
19.	Quesnel River Pulp Co. Ltd.*	Quesnel	B.C.	I
20.	Celgar Pulp Company (Power consolidated)	Castlegar	B.C.	I
21.	Proctor & Gamble Cellulose Ltd.	Grande Prairie	Alberta	I
22.	Weldwood of Canada Ltd.	Hinton	Alberta	I
23.	Weyerhaeuser Canada Ltd.	Prince Albert	Sask.	I
24.	Manfor ltd. (REPAP)*	The Pas	Manitoba	I

* CONTROL MILL – NO CHLORINE BLEACHING

DOE NO.	MILL	CITY	PROVINCE	COASTAL/INLAND
25.	Domtar Inc. (Fine Papers Div.)	Cornwall	Ontario	I
26.	C.P. Forest Products Ltd.	Dryden	Ontario	I
27.	E.B. Eddy Forest Products Ltd. (Espanola Mill Div.)	Espanola	Ontario	I
28.	Boise Cascade Canada	Fort Frances	Ontario	I
29.	James River Marathon Ltd.	Marathon	Ontario	I
30.	Domtar Inc. (Container Board Div.)	Red Rock	Ontario	I
31.	Fraser Inc.	Thorold	Ontario	I
32.	Kimberly Clark of Canada Ltd. (Terrace Bay Div.)	Terrace Bay	Ontario	I
33.	C.P. Forest Products Ltd.(Thunder Bay Div.)	Thunder Bay	Ontario	I
34.	Malette Kraft Pulp and Power	Smooth Rock Falls	Ontario	I
35.	Tembec Inc.	Témiscaming	Québec	I
36.	Cascades Inc.	Jonquière	Québec	I
37.	Les Produits Forestiers Canadien Pacifique Ltée.	La Tuque	Québec	I
38.	Produits des Pâtes et Papiers Domtar	Lebel-sur-Quévillon	Québec	I
39.	Stone Consolidated Ltd. (Div. Pontiac)	Trois-Rivières Portage-du-Fort	Québec	I
40.	Donohue St-Félicien Inc.	St-Félicien	Québec	I
41.	Industries James MacLaren Inc.	Thurso	Québec	I
42.	Stone Consolidated Ltd.	Trois-Rivières	Québec	I
43.	Les Papiers Fins Domtar	Windsor	Québec	I
44.	St. Anne-Nackawic Co. Ltd. Pulp & Paper	Nackawic	N.B.	I
45.	Miramichi Pulp & Paper	Newcastle	N.B.	I
46.	Irving Pulp & Paper Ltd.	Saint John	N.B.	I
47.	Atholville Pulp Inc.	Atholville	N.B.	I
48.	Fraser Inc.	Edmundston	N.B.	I
49.	Scott Maritime Ltd.	New Glasgow	N.S.	C
50.	Stora Forest Industries Ltd.	Port Hawkesbury	N.S.	C
51.	Western Pulp Partnership	Port Alice	B.C.	C

3.0 MATERIALS AND METHODS

3.1 SEDIMENT SAMPLING

Sediment sampling was conducted by the regional officers from both provincial and federal departments of the environment. The compatibility of the data was ensured by the use of similar and appropriate field methods for collection and storage, and the prevention of contamination (Mah et al., 1989). For samples collected prior to 1989 a protocol was not available. Field personnel adhered to the following sampling protocol (Appendix B):

All equipment used to collect samples for dioxins/furans was cleaned as follows:

1) washed with tap water and laboratory detergent;
2) rinsed with tap water and deionized water;
3) rinsed successively with pesticide grade acetone, hexane, dichloromethane, and hexane;
4) air dried and heated to >270°C for six hours.

All cleaned equipment was wrapped in heat treated (>270°C) aluminum foil until required. Ekman and Ponar dredges were cleaned according to step 1 to 3. Prior to sampling, all equipment used was rinsed with water from the sample collection site.

Sediment samples were collected with a solvent rinsed Ekman dredge, Ponar sampler or stainless steel ladle and then transferred to a stainless steel tray with a minimal amount of mixing. The top layer (≈ 1-4 cm) of the sediment sample was then transferred to a stainless steel bucket with a stainless steel spoon. This process was repeated a minimum of three times, after which the composite sample in the stainless steel bucket was mixed well. Subsamples were dispensed with a spoon into Teflon jars for dioxin/furan analysis. Polyethylene bottles were used for particle size analysis and glass jars for particulate organic carbon determinations. The subsamples for dioxin and furan, and particulate organic carbon analyses were frozen and the subsamples for particle size analysis were kept cool.

3.2 ANALYTICAL DETERMINATION OF DIOXINS AND FURANS

The sampling program put in place to assess bottom sediment contamination generated numerous samples. The laboratory method developed to detect dioxins and furans at trace levels is very laborious and time consuming. Environment Canada laboratories, the Water Quality Laboratory in Burlington (NWQL) and the River Road Environmental Technology Centre (RRETC) in Ottawa, supported by three private contract laboratories, performed the analytical work. The contract laboratories included Seakem Oceanography Ltd., Eco Logic Laboratory Inc. and Wellington Environmental Consultants Inc. The

capabilities of the private laboratories were evaluated by an inter-laboratory study (round robin) to ensure that analytical results obtained were reliable and compatible (see section 5.0 for details).

Figure 2 summarizes the analytical method (NWQL, 1989) used for analysis of dioxins and furans in sediments. Analytical procedures used by each laboratory along with quality assurance/quality control (QA/QC) procedures are described in the laboratory analytical reports (NWQL, 1989; River Road Environmental Technology Center, 1987; Seakem Oceanography, 1989; Wellington Environmental Consultants Incorporated, 1989; Eco Logic, 1989). There are differences in the clean up procedures used by the various laboratories but the analytical methods used are considered equivalent. Basically, surrogate isotopically labeled standards for each chemical class were added to each sample prior to extraction to demonstrate chemical recoveries through all phases of the extraction, clean-up and determination procedure.

Limits of detection were reported using the Practical Detection Limit (PDL) (Agemian, 1988), also designated by the expression Minimum Detection Limit (MDL) (Interlab Study II - Pulp and Paper Matrices Analytical Procedure). The Practical Detection Limit for PCDD/PCDF analysis is defined as the minimum concentration of an analyte, in a real sample-matrix, that will produce a clearly defined peak with a signal to noise ratio no less than 3:1. Variables such as sample matrix, surrogate recovery, instrument sensitivity and background noise may influence the PDL. The PDL varies from sample to sample, due to different matrix affections.

All laboratories involved in the study used the same procedure for reporting analytical results. However, the limits of detection reported by the NWQL for each compound do not vary with each sample: NWQL detection limits were calculated, for each compound, using the mean value of PDLs recorded for the overall data set. NWQL detection limits are listed in section 4.1.2.

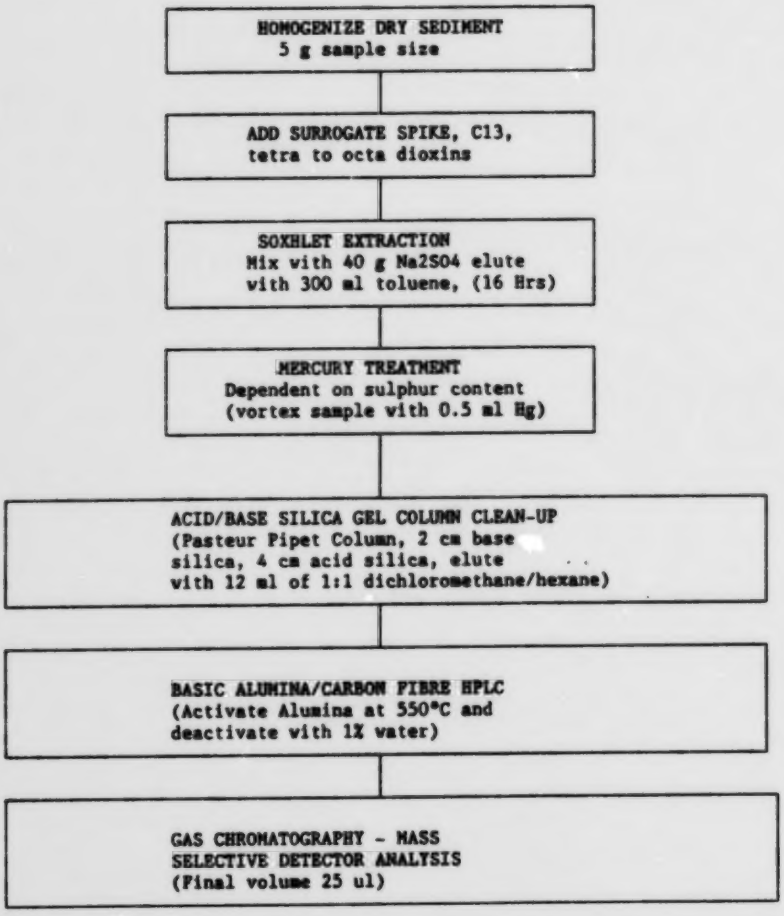
3.3 PARTICLE SIZE ANALYSIS

Sediment particle size distribution was determined with standardized methods, hydrometer, sieving, and bottom withdraval analysis. Appendix C-1 describes in detail the procedure used.

3.4 TOTAL ORGANIC CARBON ANALYSIS

Total organic carbon content in the sediment was determined using different compatible analytical methods: loss on ignition and wet oxidation. Procedures are described in detail in Appendix C-2.

Figure 2. SCHEMATIC DIAGRAM OF ANALYTICAL PROCEDURE FOR POLYCHLORINATED DIOXINS AND DIBENZOFURANS (NWQL, 1989)


HOMOGENIZE DRY SEDIMENT
5 g sample size
ADD SURROGATE SPIKE, C13,
tetra to octa dioxins
SOXHLET EXTRACTION
Mix with 40 g Na2SO4 elute
with 300 ml toluene, (16 Hrs)
MERCURY TREATMENT
Dependent on sulphur content
(vortex sample with 0.5 ml Hg)
ACID/BASE SILICA GEL COLUMN CLEAN-UP
(Pasteur Pipet Column, 2 cm base
silica, 4 cm acid silica, elute
with 12 ml of 1:1 dichloromethane/hexane)
BASIC ALUMINA/CARBON FIBRE HPLC
(Activate Alumina at 550°C and
deactivate with 1% water)
GAS CHROMATOGRAPHY - MASS
SELECTIVE DETECTOR ANALYSIS
(Final volume 25 ul)

3.5 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Quality assurance / Quality control (QA/QC) procedures are described in each of the laboratory analysis reports. A summary of the QA/QC procedures is presented in Appendix D. A detailed QA protocol (DQAC, 1989), developed by the Dioxin Quality Assurance Committee (Environment Canada) and specifically intended for the Canadian Pulp and Paper Association (CPPA) Monitoring Program, was adopted within the sediment program. In addition, other QC activities were implemented to provide essential information regarding internal laboratory practices and performances, reproducibility, bias and comparability of the analytical data.

4.0 RESULTS

Appendix E presents a list of the samples analysed by each laboratory for dioxins and furans, particle size and total organic carbon content. Laboratory codification and field label for each sample are also indicated as they were reported in field and analytical reports.

4.1 DIOXIN AND FURAN CONTAMINATION IN SEDIMENTS

Analytical results for dioxin and furan concentrations in sediment samples collected near Canadian pulp and paper mills using chlorine bleaching are presented in Appendix F.1. Concentration in pg/g or parts per trillion (ppt) on a dry weight basis (w/w) for chlorinated dibenzo-p-dioxin and dibenzofuran congener groups are indicated.

The following nomenclature is used:

T_4CDD: Tetrachlorodibenzo-p-dioxin
P_5CDD: Pentachlorodibenzo-p-dioxin
H_6CDD: Hexachlorodibenzo-p-dioxin
H_7CDD: Heptachlorodibenzo-p-dioxin
O_8CDD: Octachlorodibenzo-p-dioxin
T_4CDF: Tetrachlorodibenzofuran
P_5CDF: Pentachlorodibenzofuran
H_6CDF: Hexachlorodibenzofuran
H_7CDF: Heptachlorodibenzofuran
O_8CDF: Octachlorodibenzofuran

In this report, the term congener group will be used to refer to a single group of chlorinated dibenzo-p-dioxin (CDD) or chlorinated dibenzofuran (CDF) isomers (e.g. the T_4CDD congener group refers to the entire group of 22 isomers) as proposed by Clement and Tosine (1989).

The specific congeners 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-T_4CDD) and 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-T_4CDF), because they are among the most toxic by-products of the chlorine bleaching process, were analysed and are listed in Appendix F-1. Other specific congeners (2,3,7,8 substituted) were analysed for a limited number of samples only, and the results are presented in Appendix F-2.

4.1.1 Overview of Survey Results

A summary is presented in Table 2 of analytical results of sediment analyses grouped according to the three sampling locations, upstream and downstream for inland sites, and coastal sites. Included are the percentage of detected values, medians and ranges based on the total number of samples for each of the location. This information provides a general overview of the sediment contamination and gives an indication of the degree of sediment contamination at these locations.

Table 2. Summary of Dioxin and Furan Sediment Data. Concentrations in pg/g.

	INLAND UPSTREAM N = 38			INLAND DOWNSTREAM N = 88			COASTAL N = 27		
	%D	Range	Median	%D	Range	Median	%D	Range	Median
Dioxins									
2,3,7,8-T_4CDD	0	L15	L15	5	L15-67	L15	11	L15-28	L15
T_4CDD	0	L15	L15	6	L15-53	L15	48	L15-782	L15
P_5CDD	3	L20-37	L20	1	L20-120	L20	59	L20-1110	37
H_6CDD	5	L30-40	L30	13	L30-760	L30	77	L30-16432	775
H_7CDD	11	L50-250	L50	28	L50-10000	L50	70	L50-3431	266
O_8CDD	24	L75-960	L75	44	L75-77000	L75	74	L75-8022	266
Furans									
2,3,7,8-T_4CDF	10	L10-91	L10	52	L10-3168	16	70	L10-3179	187
T_4CDF	13	L10-192	L10	58	L10-4521	24	70	L10-4867	300
P_5CDF	0	L15	L15	11	L15-210	L15	52	L15-470	L15
H_6CDF	0	L25-78	L25	11	L25-800	L25	59	L25-1784	58
H_7CDF	5	L40-78	L40	16	L40-1100	L40	48	L40-2324	49
O_8CDF	5	L75-160	L75	14	L75-1600	L75	30	L75-680	L75

N Total number of samples
%D - % detected values, where detected values are based on national water quality laboratory (NWQL) detection limits.
L denotes values less than limit of detection: numbers following "L" represent the limit (See Section 4.1.2).

Figure 3 illustrates the percentage of mills at which dioxins and furans were detected in sediments.

The following observations can be made:

- The frequency of detection and levels of contamination differ in coastal and inland sites.

- Inland upstream sites are generally not contaminated by CDDs or CDFs (unless contaminated from upstream mill). Medians are less than detection limits. Very few samples showed results greater than detection limits.

- At inland downstream sites, the contamination by CDDs and CDFs showed frequencies of detection higher than in upstream sites. Contamination of downstream sites is mainly due to the presence of tetrachlorinated furan and octachlorinated dioxins.

- Frequency and median concentrations of contaminated sediments at coastal mills for all CDD and CDF are higher than at inland mills (Table 2). Coastal sites are contaminated by a mixture of CDDs and CDFs.

- Frequency of detected values for CDDs increases with increased chlorine substitution (tetra to octachlorinated). This trend is not observed for CDFs. Tetrachlorinated furan is more frequently detected than octachlorinated furan in sediments.

- While 2,3,7,8-T_4CDD is relatively absent in the sediment collected, contamination by 2,3,7,8-T_4CDF is much more evident and appears at a majority of inland downstream and coastal sampling sites.

- Inland downstream sites show very little evidence of contamination by penta, hexa and hepta chlorinated dioxins and furans as opposed to coastal sites (Figure 3).

4.1.2 Data Analysis Procedure

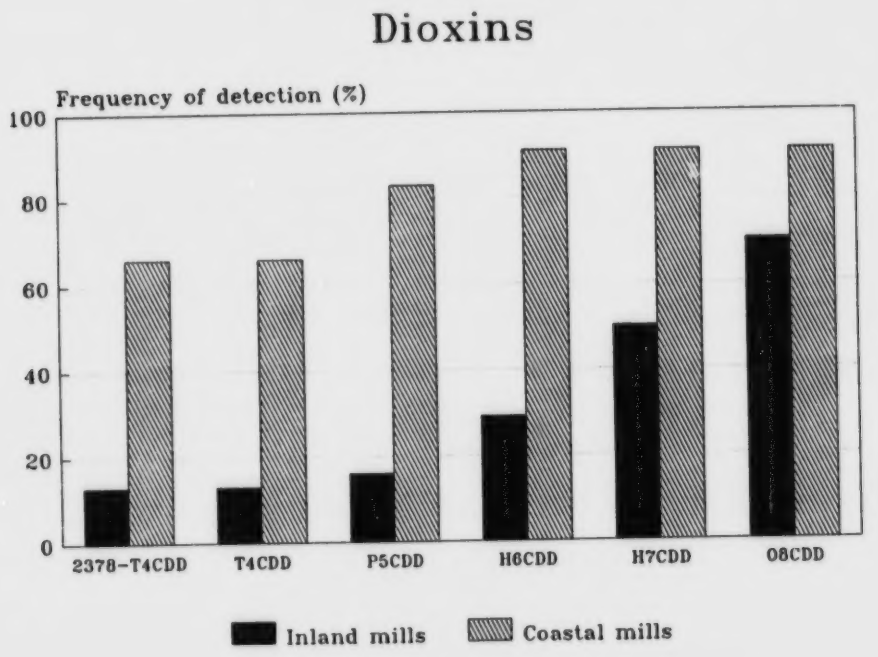
Following the initial grouping of data (section 4.1.1, overview), considerable time and effort was expended to:

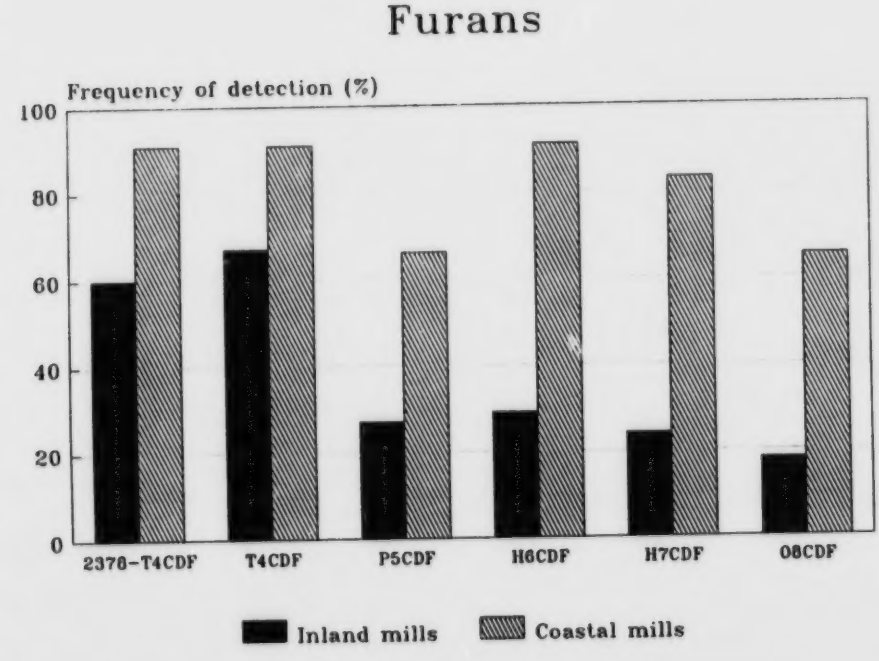
i) Better visualise the overall data distribution and condense the data;
ii) Summarize the degrees of contamination encountered during the survey;
iii) Characterize contamination at each site using a classification system.

Close examination of the data revealed the following characteristics:

- a high number of nondetectable values;
- detection limits for the same compound that fluctuated with samples and among participating analytical laboratories;
- a very large range of detected values (over three orders of magnitude) which varies among CDD and CDF congeners

FIGURE 3. PERCENTAGE OF MILLS (12 COASTAL AND 35 INLAND) AT WHICH DIOXINS OR FURANS WERE DETECTED IN SEDIMENTS





- no uniform sampling allocation (number of sampling sites per mills varies from 1 to 6)
- absence of extensive QA/QC program resulting in a low confidence in some of the results (see Section 4.3).

To carry out the data assessment and meet the above objectives, a preliminary data screening and an innovative method for data classification specifically adapted to the data particularities was developed as described below. The Toxicity Equivalency (TEQ) concept used to summarize the data is also described.

Treatment of "Censored Data Set"

To overcome difficulties related to the assessment of data sets containing high numbers of measurements less than the detection limit (censored data) a data screening method was required. This problem was further complicated with different ways of reporting limits of detection, limits of detections largely fluctuating and by inconclusive QA/QC results at low concentrations of dioxins and furans (see section 4.3 for details). The situation was addressed in the following way:

> **Limits of detection reported by the Water Quality Branch laboratory (NWQL) were used as benchmark values to delimit a class for data considered to be, or assigned as "less than limits of detection". Consequently, a "less than detection limit value" is assigned to any result with a value less than the NWQL limit of detection by default and will be included in this class whether it is or is not detected by the laboratory which provided the result.**

However this procedure, to treat as less than detection limit data, resulted in the rejection of useful information since NWQL limits of detection were usually higher than the other laboratories. This procedure did permit the assessment of the data fairly and consistently, and independently of the large range of detection limit values reported for a single compound. It also greatly simplified data analysis and interpretation. Moreover, low levels of confidence at these levels were observed. Raw data reported with original detection limits are presented in Appendix F-1.

Limits of detection reported by the NWQL and used in the treatment of the data in this report are listed below:

2,3,7,8-T4CDD:	15 pg/g	2,3,7,8-T4CDF:	10 pg/g
T_4CDD:	15 pg/g	T_4CDF:	10 pg/g
P_5CDD:	20 pg/g	P_5CDF:	15 pg/g
H_6CDD:	30 pg/g	H_6CDF:	25 pg/g
H_7CDD:	50 pg/g	H_7CDF:	40 pg/g
O_8CDD:	75 pg/g	O_8CDF:	75 pg/g

Therefore, for all further calculation or data comparisons, values equal to or lover than the above limits of detection will be replaced and included in the less than detection limit class (e.g. 7 pg/g of

2,3,7,8-T_4CDF at site 22B is classified in "less than detection limit" class because it is less than 10 pg/g, the NWQL limit of quantitation for this compound).

When a result was reported as "less than detection limit" with a limit of detection greater than the NWQL limit of quantitation, a value of half of the detection limit was assigned and used for further result computations (Gilbert,1987); e.g. P_5CDD at site 42C reported as L103 pg/g was assigned a value of 51.5 pg/g.

Toxicity Equivalents of 2,3,7,8-T_4CDD

A mixture of CDDs and CDFs, though not equally toxic, can be examined using Toxicity Equivalent values (TEQ). TEQ values are established in relation to the most toxic compound in this family of chemicals, the 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-T_4CDD). TEQs are calculated using internationally accepted toxic equivalency factors (I-TEF) which are listed in Table 3.

TABLE 3 INTERNATIONAL TOXICITY EQUIVALENCY FACTORS (AFTER NATO, 1988)

Dioxin/Furan	Equivalency Factor
2,3,7,8-T_4CDD	1
1,2,3,7,8-P_5CDD	0.5
1,2,3,4,7,8-H_6CDD 1,2,3,7,8,9-H_6CDD 1,2,3,6,7,8-H_6CDD	0.1
1,2,3,4,6,7,8-H_7CDD	0.01
O_8CDD	0.001
2,3,7,8-T_4CDF	0.1
2,3,4,7,8-P_5CDF	0.5
1,2,3,7,8-P_5CDF	0.05
1,2,3,4,7,8-H_6CDF 1,2,3,7,8,9-H_6CDF 1,2,3,6,7,8-H_6CDF 2,3,4,6,7,8-H_6CDF	0.1
1,2,3,4,6,7,8-H_7CDF 1,2,3,4,7,8,9-H_7CDF	0.01
O_8CDF	0.001

In the present study, the I-TEF concept provides a uniform approach for summarizing analytical data and for indicating the toxicological significance of dioxins and furans; it provided a useful basis for comparison of site specific contamination. The TEQ provides a convenient means of summarizing the extensive amount of analytical data resulting from a detailed gas chromatograph/mass spectrometry (GC/MS) investigation from a hazard assessment point of view (NATO, 1988). The I-TEF are used as an interim procedure for assessing the potential hazard resulting from exposure to a mixture of CDDs and CDFs (NATO, 1988).

The concentration of a given dioxin or furan is multiplied by the factor listed in Table 3 and the sum of the congeners is made. It must be noted that the TEQs are used only as a yardstick or an indicator of presence of particular problems or "hot spot" and can not be used as a measure of toxicity or hazard assessment.

To apply the I-TEF scheme to the sediment data, the following assumption was made:

> All of the penta, hexa, hepta and octachlorinated dioxins and furans are 2,3,7,8-substituted congeners which constitutes a worst case scenario, an overestimate and a conservative approach resulting in maximum toxicity equivalency values.

Except for the two congener-specific 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF, analytical data were reported for congener groups; e.g. the total amount of P_5CDD, H_6CDD, etc., without distinguishing between the individual isomers. The TEFs are developed for congener-specific data and refer to the 2,3,7,8-substituted congeners. (The congener specific data generated by the three commercial laboratories (Appendix F-2) are incomplete and, in some cases, not meaningful because of their high detection limits.)

It should be noted that, in the absence of information concerning the congener composition of the pulp and paper mill sources, tetra- and penta-CDDs and CDFs contribute significantly to the TEQs due to the magnitude of their respective TEFs (Table 3). Considering that the TEQ calculation is already overestimated (when congener groups are used), it was decided to choose the lovest TEF (0.05) for the penta-CDF congener group as a compromise.

The TEF values presented in Table 3 also suggest that penta-CDDs and penta-CDFs estimates would represent a major contribution and potentially augment the error in the TEQ estimation more than would other congener groups (hexa and hepta). In that respect, the contribution of each congener group to the calculations of TEQ is illustrated at sites with high values of TEQ to identify the sources of the TEQ estimation. These figures can also be used to show the relative importance of the congener groups.

When a measurement was lover than the detection limit, TEQs were calculated with an assigned value equal to half of the limit of

detection (reported by NWQL, listed on page 13). The detailed procedure used to generate the TEQ values that appear in section 4.1.3.2 is given in Appendix H. To summarize TEQ results, the classification procedure described below in this section was used. This ensured that the data was analyzed uniformly and consistently.

Classification of Contamination Levels

There are no limits, standards, guidelines or sediment quality criteria available to assess the significance of sediment contamination by CDDs and CDFs. Also the data are not normally distributed and conventional parametric descriptors (mean, standard deviation) cannot be applied. To perform an objective classification exercise, the use of the median value as a yardstick was adopted to group data into classes of increasing contamination and to delimit class intervals. The use of the median, although arbitrary, was judged the best alternative considering the non-normal distribution of the data. This pragmatic approach, where the ranking of contamination levels is done solely in light of the present survey data, avoids using intuitive judgment or subjective delimitation of the contamination classes. The classification system was developed with the assistance of the Applied Statistics Division (D. MacLeod, 1990, pers. comm., Environment Canada).

For each CDD and CDF congener groups and for TEQs, the median value was computed for coastal and inland downstream sampling sites respectively. As indicated previously, contamination differs substantially between coastal and inland downstream sampling sites; data assessment was carried out keeping these two groups apart.

Five contamination classes or categories were created as indicated below. Provision was made for a sixth class if required.

1) Less than or equal to limit of detection
<= DETECTION LIMIT

2) Limit of detection to the median value
DETECTION LIMIT - MEDIAN

3) Median value to three times the median value
MEDIAN - 3X MEDIAN

4) Three times median value to ten times the median value
3X MEDIAN - 10X MEDIAN

5) Ten times median value to thirty times the median value
10X MEDIAN - 30X MEDIAN

6) Results greater than thirty times the median value
> 30X MEDIAN

If the median is equal to the limit of detection, the second category is eliminated. The multiplying factor chosen corresponds to the base 3 raised to power 1,2,3 (3^1, 3^2, 3^3) and rounded up to 10 and 30 to get convenient value and facilitate calculations. From this point results can be compared and classified by using a common denominator.

4.1.3 Presentation of results and interpretation

4.1.3.1 GENERAL CHARACTERISTICS OF COASTAL AND INLAND SEDIMENTS

Contamination Levels

Results are assessed in terms of contamination ranges and classes, and frequency distribution of coastal and inland downstream sediments. Results of the classification procedure are illustrated in Appendix G.

The following observations can be made:

- Differences between coastal and inland downstream sites are evident: Concentration at coastal sites are much higher than at inland downstream sites for most CDD and CDF congeners. However, 2,3,7,8-T_4CDD (mostly under the detection limit), P_5CDF, H_7CDF and O_8CDF were found at similar contamination levels at coastal and inland downstream sites.

- Sediments at coastal sites were higher in concentrations of T_4CDD (other than 2,3,7,8-T_4CDD), P_5CDD, H_6CDD, H_7CDD, O_8CDD, 2,3,7,8-T_4CDF and T_4CDF when compared to downstream inland sites.

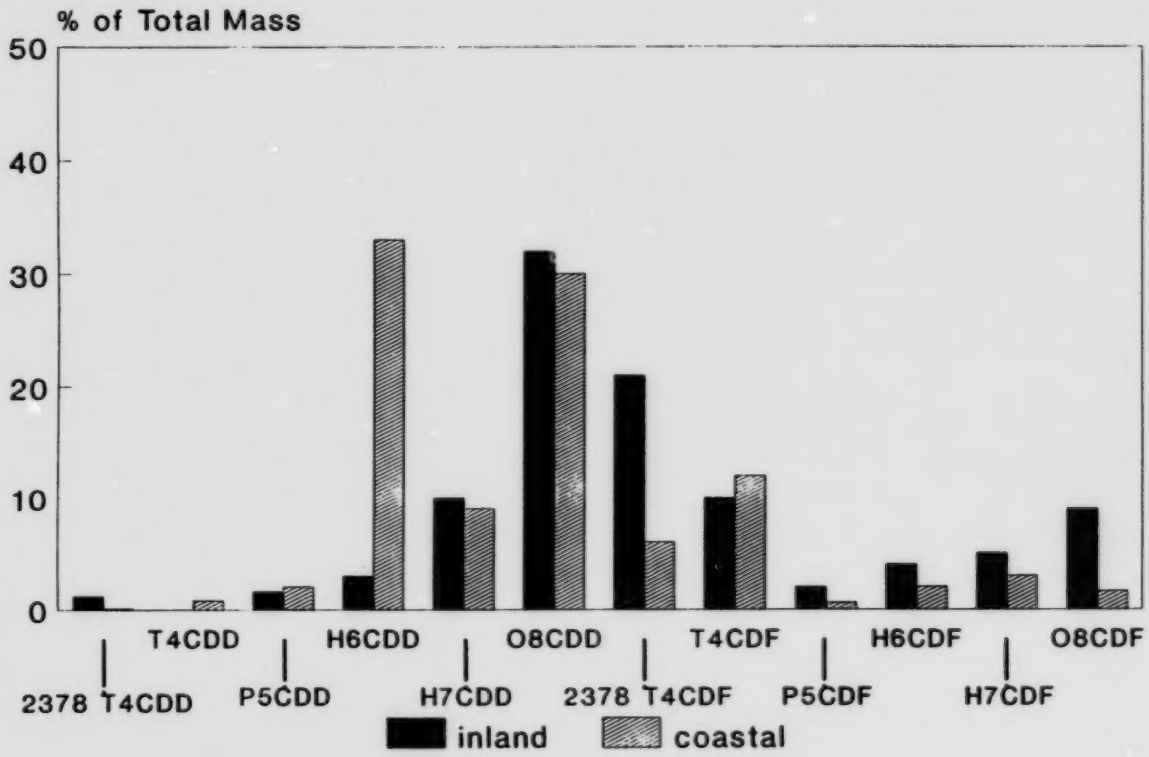
- Inland downstream sites were characterized by the presence of only a few congeners, the 2,3,7,8-T_4CDF, T_4CDF and O_8CDD. The concentrations of these congeners are significantly smaller at inland sites than coastal sites.

- CDDs with high chlorine substitution (hexa to octa) were more abundant in sediments than CDDs with low degree of chlorination. CDFs did not show such a trend.

Profile of Dioxins and Furans in Sediments

The distribution of dioxins and furans in coastal and inland sediments is shown in Figure 4. The congeners 2,3,7,8-T_4CDF and O_8CDD are predominant congeners at inland sites. At coastal sampling sites, the contamination of sediments is mainly due to a high proportion of H_6CDD, T_4CDF and O_8CDD.

FIGURE 4. DISTRIBUTION OF DIOXIN AND FURAN CONGENERS IN SEDIMENTS FROM INLAND AND COASTAL SAMPLING SITES



Total Mass: Sum of PCDDs and PCDFs for all the samples

Toxicity Equivalents

Toxicity Equivalents (TEQs) were caculated at each sampling site, using the I-TEF (Table 3). Results are presented in Appendix H. The levels and frequency distribution of TEQ values for coastal and downstream inland sampling sites are illustrated in Figure 5.

The TEQ median value at coastal sites is greater, by almost an order of magnitude, than the median value at downstream inland sites (150 and 20 TEQ of 2,3,7,8-T_4CDD in pg/g, respectively), indicating that coastal sediments are more heavily contaminated than inland sediments.

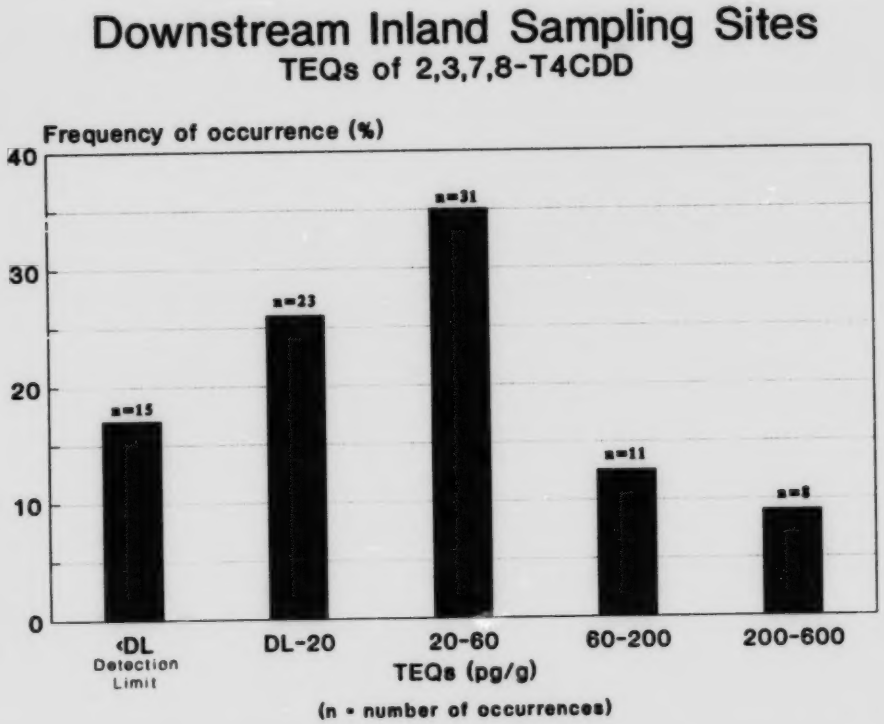
4.1.3.2 SITE SPECIFIC CHARACTERISTICS

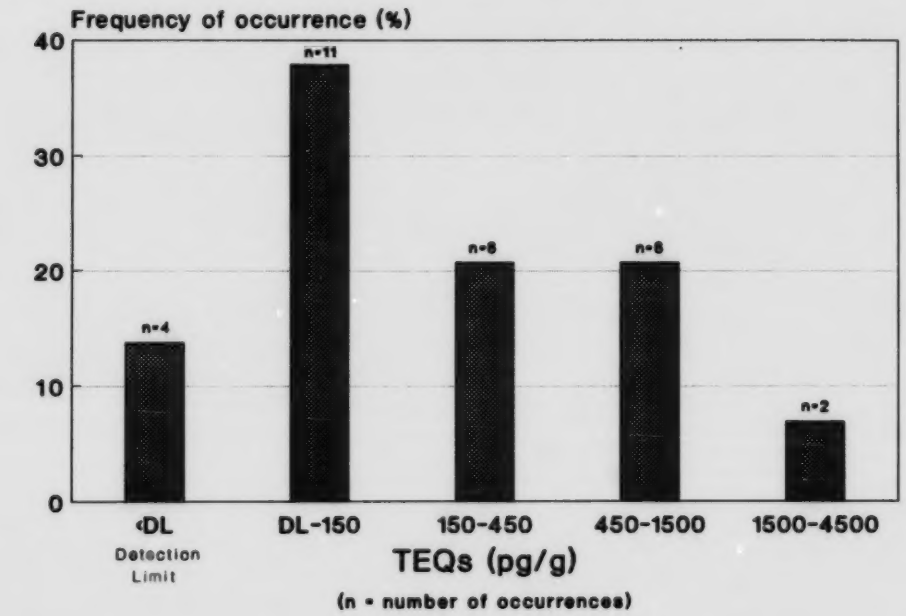
The use of a classification approach to summarize the overall data on CDDs and CDFs in sediment also permits one to characterize the level of contamination at each site. It provides a relative estimation of the quality of the sediments and of the contamination levels encountered at different sampling sites.

A site specific examination of TEQs and intersite comparison can be easily done by referring to Figures 6a to 6f which show TEQ study results for coastal (British Columbia and Nova Scotia) and inland sampling sites (British Columbia, Prairies, Ontario, Quebec and New-Brunswick). These figures allow one to get a broad perspective of the contamination level encountered in the survey and rapidly identify "hot spots".

To provide more detailed information, Figures 7a to 7f illustrate for each sampling site the contamination levels of CDD and CDF congener groups according to the classes previously defined. The use of classes makes the comparisons (rather than comparing raw data) of upstream and downstream, and intrasite and intersite data easier. Legends for the classification of congener group data are presented on fold-out pages number 29 and 63 for coastal and inland sites, respectively.

FIGURE 5. FREQUENCY DISTRIBUTION FOR TEQs OF 2,3,7,8-T_4CDD CLASSES - COMPARISON BETWEEN COASTAL AND DOWNSTREAM INLAND SAMPLING SITES





To illustrate the relative contribution of the congener groups to the toxicity equivalency, Figures 8a to 8d present the results for selected sampling sites and help to illustrate the importance of the congener group.

Although it would be of interest to analyse the contamination results site by site, it is not feasible in the context of the present report to scrutinize the information available at every sampling site.

To perform a detailed interpretation, sampling sites showing the highest TEQ concentrations at each mill have been identified for the following discussion. For the purposes of the following discussion, the different contamination classes are identified as following:

>30X median	Highest
10X-30X median	Very high
3X-10X median	High
1X-3X median	Intermediate
DL-median	Low or slight
<=DL	Not detected (Lower than limit of detection)

The following description of site specific characterics are based on TEQ results, the classification of contamination levels and the relative contribution of the congener groups.

COASTAL SAMPLING SITES

BRITISH COLUMBIA AND NOVA SCOTIA

Figure 6a shows that, from a total of 12 pulp and paper mills (10 mills in B.C. and two mills in N.S.) discharging effluents into the coastal aquatic environment, sediments collected close to the Western Pulp Partnership (Squamish, B.C.) - sampling site #17A, and the MacMillan Bloedel - sampling site #8A, indicated the "highest" contamination level (1,500-4,500 pg/g TEQs).

As summarized in Table 4, at four other mills, at least one sampling site was contaminated at "high" contamination level (450-1,500 pg/g TEQs).

Table 4. Summary of Contamination Characterization Based on the Highest TEQs for Coastal Sampling Sites.

VERY HIGH	
Site #8 A - MacMillan Bloedel, Port Alberni	B.C.
Site #17 A - Western Pulp Partnership, Squamish	B.C.
HIGH	
Site #2 B,C - Fletcher Challenge Can.,Crofton	B.C.
Site #7 B - MacMillan Bloedel, Nanaimo	B.C.
Site #9 A - Canfor Products, Port Mellon	B.C.
Site #10 A - MacMillan Bloedel, Powell River	B.C.
INTERMEDIATE	
Site #3 A - C.P Forest Products, Gold River	B.C.
Site #14 B - Skeena Cellulose, Prince Rupert	B.C.
SLIGHTLY CONTAMINATED OR NOT DETECTED	
Site #1 - Fletcher Challenge, Campbell River	B.C.
Site #49 - Scott Maritimes, New Glasgow	N.S.
Site #50 - Stora Forest Products, Port Havkesbury	N.S.
Site #51 - Western Pulp Partnership, Port Alice	B.C.

Out of a total of 29 sampling sites in the two provinces, 15 sites were "not detected" or "slightly" contaminated, six sites were "intermediately" contaminated and eight were "highly" or "very highly" contaminated.

The common characteristic of the contaminated sites is the predominance of H_6CDD which contributes significantly to the TEQs illustrated in Figure 8a. At sites #2B, #7B and #8A, the presence of P_5CDD contributed considerably to the magnitude of the TEQs.

Examination of Figure 7a illustrates other interesting information:

- Site #17A and #17B are characterized by the highest concentration of 2,3,7,8-T_4CDF.

- 2,3,7,8-T_4CDD was detected at sites #17A and #9A (Hove Sound), and #14B (Prince Rupert), with concentrations of 17, 25 and 27 pg/g respectively. Detection of this congener in sediments had been confirmed by two baseline surveys conducted in 1989 (Hatfield Consultants, 1989a, 1989b). The concentrations of 2,3,7,8-T_4CDD at sites #2 (Crofton), #3 (Gold River), #7(Nanaimo), #8 (Port Alberni) and #10 (Powell River) were detected but below the limit of detection (<15 pg/g). Environmental surveys have also been requested in these areas (Hatfield Consultants, 1990a,b,c,d; Beak Associates Consulting, 1990).

- Site #17A is classed as "very high" for P_5CDD.

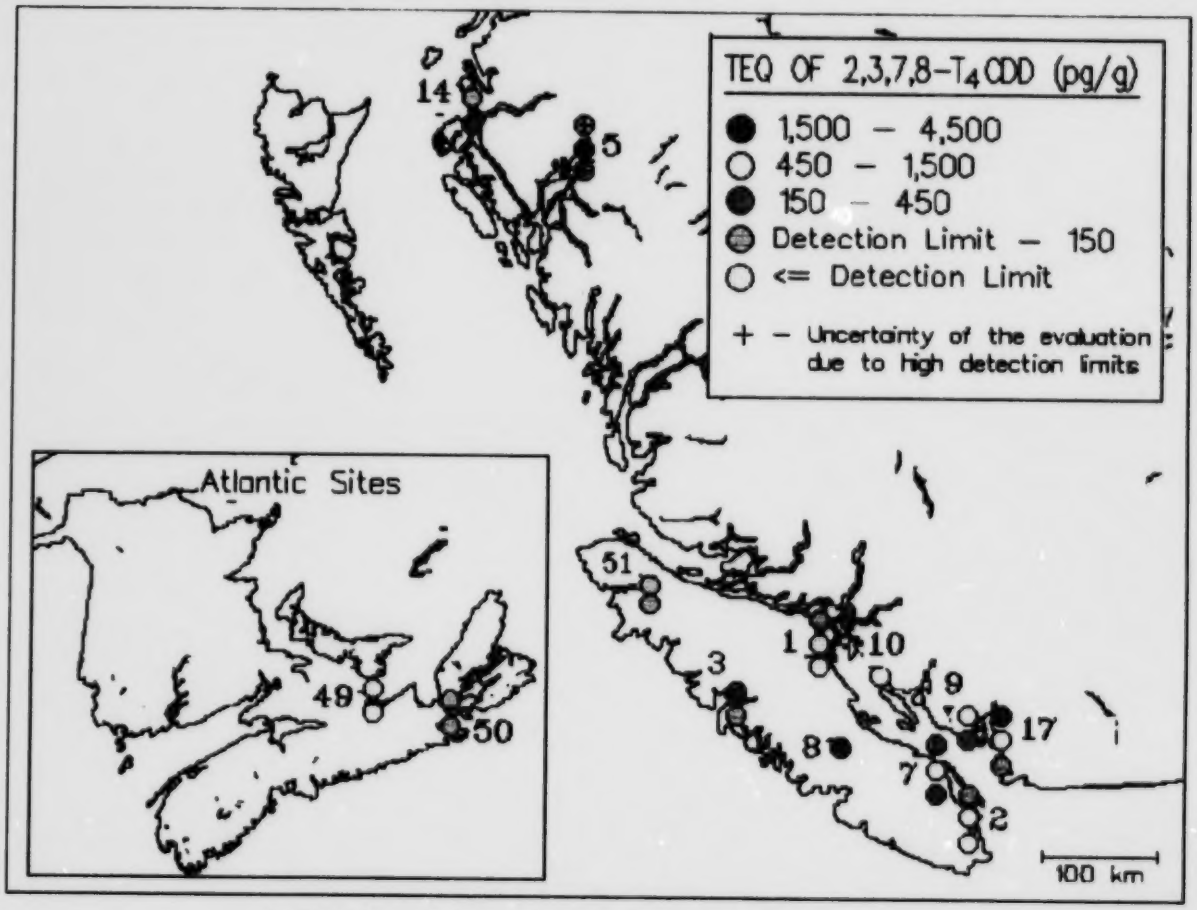
Eurocan is an inland mill. Sampling sites #5 G, H and I are included here because of their coastal location. Inland sampling site will be discused in section on B.C. inland.

It should be noted that Eurocan coastal sampling sites #5 G,H,I are close to an aluminum smelter located in the inlet which can influence sediment contamination by presence of higher concentration of dioxin and furan.

Figure 6a

Sediment Contamination Expressed as 2,3,7,8 - T_4CDD Equivalents (pg/g)

British Columbia & Nova Scotia - Coastal Sites



1. Fletcher Challenge Canada Ltd. – Campbell River, B.C.
2. Fletcher Challenge Canada Ltd. – Crofton, B.C.
3. C.P. Forest Products Ltd. – Gold River, B.C.
5. Eurocan Pulp and Paper Ltd. – Kitimat, B.C. *
7. MacMillan Bloedel Ltd. – Nanaimo, B.C.
8. MacMillan Bloedel Ltd. – Port Alberni, B.C.
9. Canfor Products Ltd. – Port Mellon, B.C.
10. MacMillan Bloedel Ltd. – Powell River, B.C.
14. Skeena Cellulose Inc. – Prince Rupert, B.C.
17. Western Pulp Partnership Ltd. – Squamish, B.C.
49. Scott Maritimes Ltd. – New Glasgow, Nova Scotia
50. Stora Forest Products – Port Hawkesbury, Nova Scotia
51. Western Pulp Partnership Ltd. – Port Alice, B.C.

* Control Mill – No Chlorine Bleaching

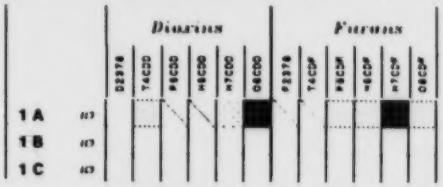
Figure 7a

CLASSIFICATION OF CONTAMINATION LEVELS

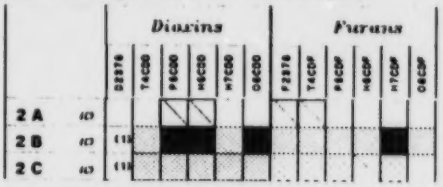
(See legend on page 29 for class limits)

British Columbia and Nova Scotia - Coastal Sites

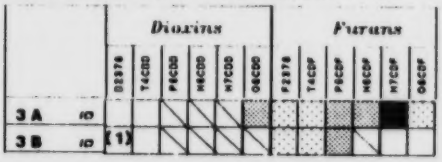
1. Fletcher Challenge Canada Ltd. - Campbell River, B.C.



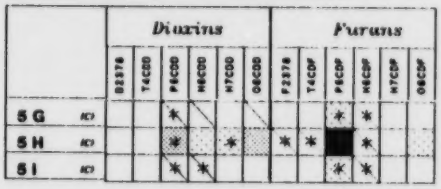
2. Fletcher Challenge Canada Ltd. - Crofton, B.C.



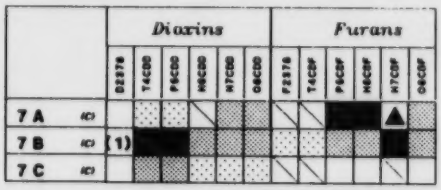
3. C.P. Forest Products Ltd. - Gold River, B.C.



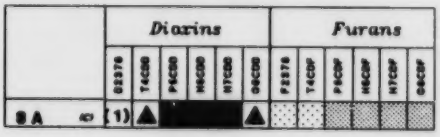
6. Eurocan Pulp and Paper Ltd. - Kitimat, B.C. (2)



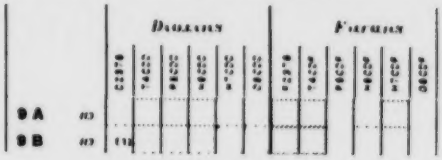
7. MacMillan Bloedel Ltd. - Nanaimo, B.C.



8. MacMillan Bloedel Ltd. - Port Alberni, B.C.

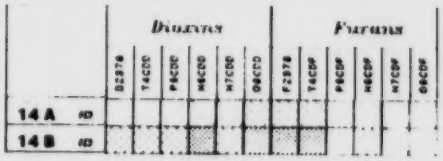


9. Canfor Products Ltd. - Port Mellon, B.C.

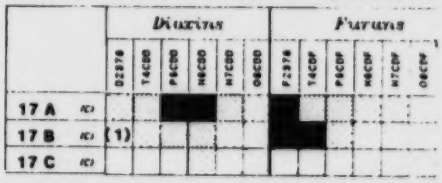


10. MacMillan Bloedel Ltd. - Powell River, B.C.

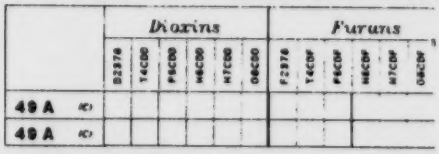
14. Skeena Cellulose Inc. - Prince Rupert, B.C.



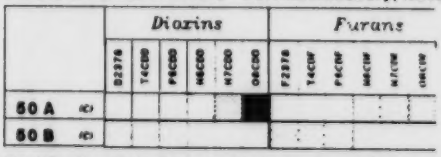
17. Western Pulp Partnership Ltd. - Squamish, B.C.



49. Scott Maritimes Ltd. - New Glasgow, Nova Scotia



50. Stora Forest Products - Port Hawkesbury, Nova Scotia



51. Western Pulp Partnership Ltd. - Port Alice

* - Uncertainty due to high detection limits

(1) - Detected at < 15 pg/g

(2) - No Chlorine Bleaching

LEGEND

CLASSIFICATION OF CONTAMINATION LEVELS
COASTAL SITES

Legend

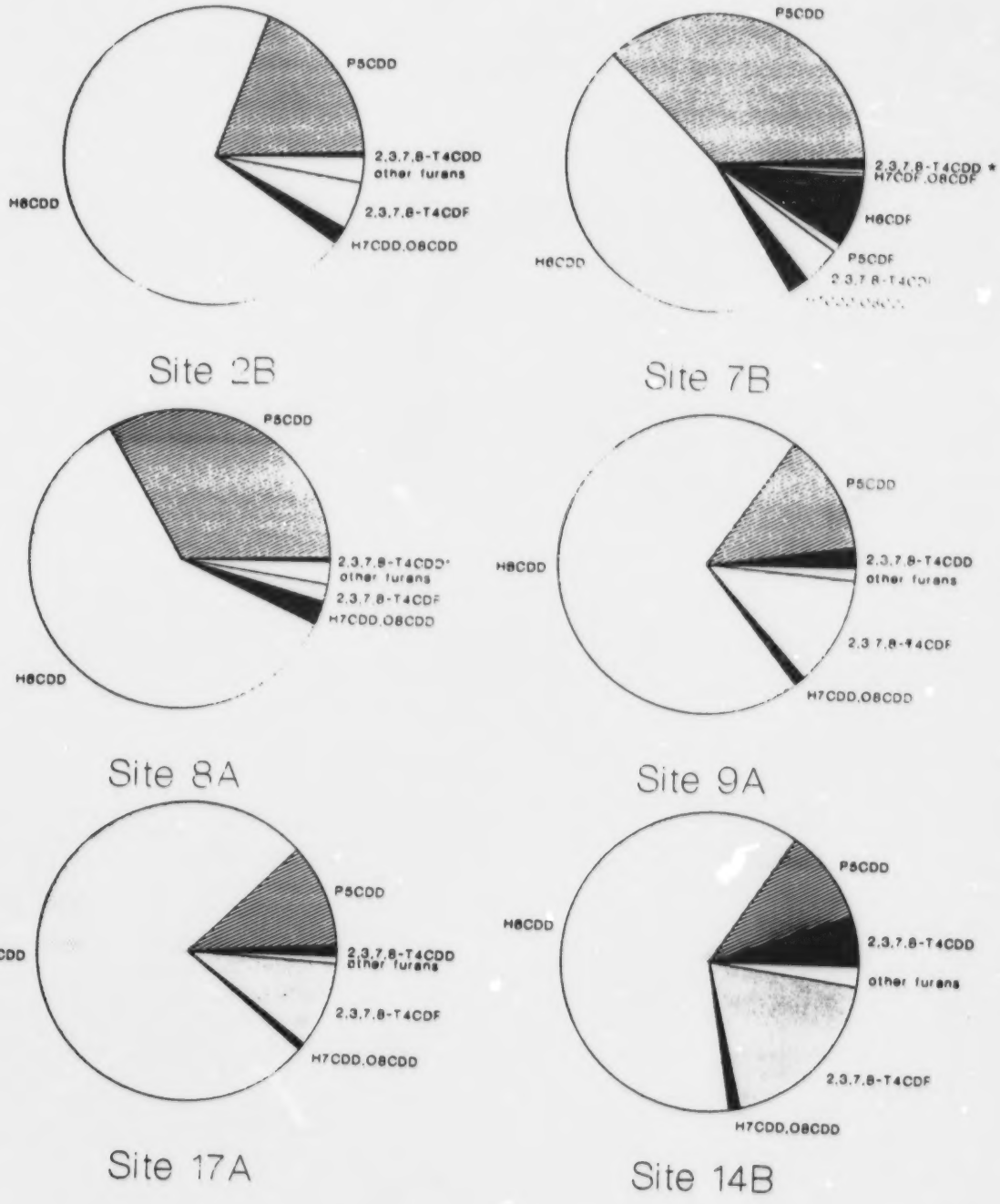
Classification of Contamination Levels
Coastal Sites

□ < Detection Limit ▨ Low or Slight ▨ Intermediate ▨ High ■ Very High ▲ Highest

Dioxins		*Furans*	
CONGENERS	**CONCENTRATIONS (pg/g)**	**CONGENERS**	**CONCENTRATIONS (pg/g)**
D2378 (2,3,7,8-T4CDD)	□ <= 15 ▨ No Class(1) ▨ 15 - 45	F2378 (2,3,7,8-T4CDF)	□ <= 10 ▨ 10 - 200 ▨ 200 - 600 ▨ 600 - 2,000 ■ 2,000 - 6,000
T4CDD	□ <= 15 ▨ No Class(1) ▨ 15 - 45 ▨ 45 - 150 ■ 150 - 450 ▲ > 450	T4CDF	□ <= 10 ▨ 10 - 300 ▨ 300 - 900 ▨ 900 - 3,000 ■ 3,000 - 9,000
P5CDD	□ <= 20 ▨ 20 - 40 ▨ 40 - 120 ▨ 120 - 400 ■ 400 - 1,200	P5CDF	□ <=15 ▨ No Class(1) ▨ 15 - 45 ▨ 45 - 150 ■ 150 - 450
H6CDD	□ <= 30 ▨ 30 - 800 ▨ 800 - 2,400 ▨ 2,400 - 8,000 ■ 8,000 - 24,000	H6CDF	□ <= 25 ▨ 25 - 60 ▨ 60 - 180 ▨ 180 - 600 ■ 600 - 1,800
H7CDD	□ <= 50 ▨ 50 - 250 ▨ 250 - 750 ▨ 750 - 2,500 ■ 2,500 - 7,500 ▲ > 7,500	H7CDF	□ <= 40 ▨ 40 - 50 ▨ 50 - 150 ▨ 150 - 500 ■ 500 - 1,500 ▲ > 1,500
O8CDD	□ <= 75 ▨ 75 - 250 ▨ 250 - 750 ▨ 750 - 2,500 ■ 2,500 - 7,500 ▲ > 7,500	O8CDF	□ <= 75 ▨ No Class(1) ▨ 75 - 225 ▨ 225 - 750

(1) - When the median is equal to the detection limit a "low or slight" contamination class is not created

FIGURE 8a. RELATIVE CONTRIBUTION OF CONGENER GROUPS TO THE TEQs AT SELECTED COASTAL SAMPLING SITES - BRITISH COLUMBIA



*Value less than detection limit: the assigned value is used in the pie chart

INLAND SAMPLING SITES - OVERVIEW

As summarized in Table 5, the following general comments can be made regarding the sediment contamination at inland sampling sites:

- Out of a total of 39 inland pulp and paper mills (total including control mills), five mills discharging into the freshwater aquatic environment had contaminated sediments to "very high levels" (200-600 pg/g TEQs). At five other mills, sediments collected were "highly" contaminated (60-200 pg/g TEQs). These mills are located in British Columbia, Ontario and Québec.

- At 15 mills, dioxins and furans were present in "slightly or not detected" contamination classes (less than 20 pg/g TEQs). At the remaining 14 mills, contamination levels were "intermediate" (20-60 pg/g TEQs).

Out of a total of 88 downstream sampling sites, 40 sites were classified as "slightly" contaminated or not contaminated at detection levels. Of the remaining sites, 19 were contaminated at "high" to "very high" levels of contamination.

The 2,3,7,8-T_4CDD was detected at three locations: #26 (C.P. Forest Products, Lake Superior), #32 (Kimberly Clark, Lake Superior) and #38 (Produits des Pâtes et Papiers Domtar, R. Quévillon) with concentrations ranging from 17 to 67 pg/g. The concentrations of 2,3,7,8-T_4CDD at sites #28 (Boise Cascade, Rainy R.) and #37 (Produits Forestiers C.P., St-Maurice R.) were detected below the limit of detection (less than 15 pg/g).

Table 5. Summary of Contamination Characterization Based on the Highest TEQs for Inland Sampling Sites.

VERY HIGH	
Site #4 D,E - Weyerhaeuser Can., Kamloops	B.C
Site #6 D - Fletcher Challenge Can., Mackenzie	B.C
Site #16 C - Crestbrook Forest Ind., Cranbrook	B.C
Site #26 C - Canadian Pacific Forest Prod., Dryden	ONT.
Site #30 A,B,C - Domtar Inc., Red Rock	ONT.
HIGH	
Site #20 D - Celgar Pulp Com., Castlegar	B.C.
Site #25 B,C - Domtar Inc, Cornwall	ONT.
Site #29 E - James River Marathon, Marathon	ONT.
Site #32 B,C - Kimberly Clark of Can., Terrace Bay	ONT.
Site #38 A - Produits Pâtes & Papiers Domtar, Lebel Quév.	QUE.
INTERMEDIATE	
Site #5 F* - Eurocan Pulp & Paper, Kitimat / Control mill	B.C.
Site #11 B,C,D - Northwood Pulp & Timber, Prince George	B.C.
Site #12/13 E,F - Canfor Prince George Pulp & Paper/ Prince George Pulp & Inter., Prince George	B.C.
Site #15 B,C,D - Cariboo Pulp & Paper, Quesnel	B.C.
Site #18 A,C - Finlay Forest Ind., Mackenzie/ Control Mill	B.C.
Site #19 A,D,F - Quesnel River Pulp, Quesnel/ Control Mill	B.C.
Site #27 B,C - E.B. Eddy Forest Prod., Espanola	ONT.
Site #31 A* - Fraser Inc., Thorold	ONT.
Site #37 A - Produits Forestiers Canadiens Pac., La Tuque	QUE.
Site #39 A - Stone Consolidated Inc., Portage-du-Fort	QUE.
Site #42 B*,C*,D* - Stone Consolidated, Trois-Rivières	QUE.
Site #44 C,D - St. Anne Nackawic, Nackawic	N.B.
Site #45 A,B - Miramichi Pulp & Paper, Newcastle	N.B.
SLIGHTLY CONTAMINATED OR NOT DETECTED	
Site #21 - Proctor & Gamble Cellulose, Grande Prairie	ALB.
Site #22 - Welwood of Canada, Hinton	ALB.
Site #23 - Weyerhaeuser Canada, Prince Albert	SAS.
Site #24 B - Manfor Ltd (Repap), The Pas / Control Mill	MAN.
Site #28** - Boise Cascade Can., Fort Frances	ONT.
Site #33 - C.P. Forest Products, Thunder Bay	ONT.
Site #34 - Malette Kraft Pulp & Power, Smooth Rock Falls	ONT.
Site #35 - Tembec Inc., Temiscaming	QUE.
Site #36 - Cascades Inc., Jonquière	QUE.
Site #40 - Donohue St-Félicien, St-Félicien	QUE.
Site #41 - Industries James Maclaren Inc, Thurso	QUE.
Site #43 - Les Papiers Fins Domtar, Windsor	QUE.
Site #46 - Irving Pulp & Paper, Saint John	N.B.
Site #47 - Atholville Pulp & Paper, Atholville	N.B.
Site #48 - Fraser Inc., Edmundston	N.B.

* Uncertainty of the evaluation due to high detection limits
**uncompleted analysis
Control Mill - no chlorine bleaching

BRITISH COLUMBIA

As shown in Figures 6b and 7b, at four of the 8 mills located in British Columbia, at least one sampling site per mill was contaminated at "very high" (200-600 pg/g TEQs) to "high" levels (60-200 pg/g TEQs).

- Sites #4D and #E, #6D, 6E and 6F, #16C and #20D were contaminated by the highest levels of 2,3,7,8-T_4CDF.

- Site #18 (Finlay Forest Industries) is a control mill (no bleaching) and concentrations of dioxins and furans might reflect the influence of contamination from site #6 (Fletcher Challenge Canada) located approximately 6 km further south on Williston Lake. In addition to 2,3,7,8-T_4CDF, sites #6D, E and F revealed the presence of O_8CDD. Both 2,3,7,8-T_4CDF and O_8CDD are found in sediments from site #18.

- At site #19, a control mill, concentrations of 2,3,7,8-T_4CDF and T_4CDF were found in upstream as well as in downstream sediments. This may reflect the influence of mills #11, #12, and #13 located on the same river, the Fraser, in Prince George.

- Site #15 in Quesnel is located downstream of four mills (of which three used chlorine bleaching) and consequently it is difficult to differentiate contaminant sources.

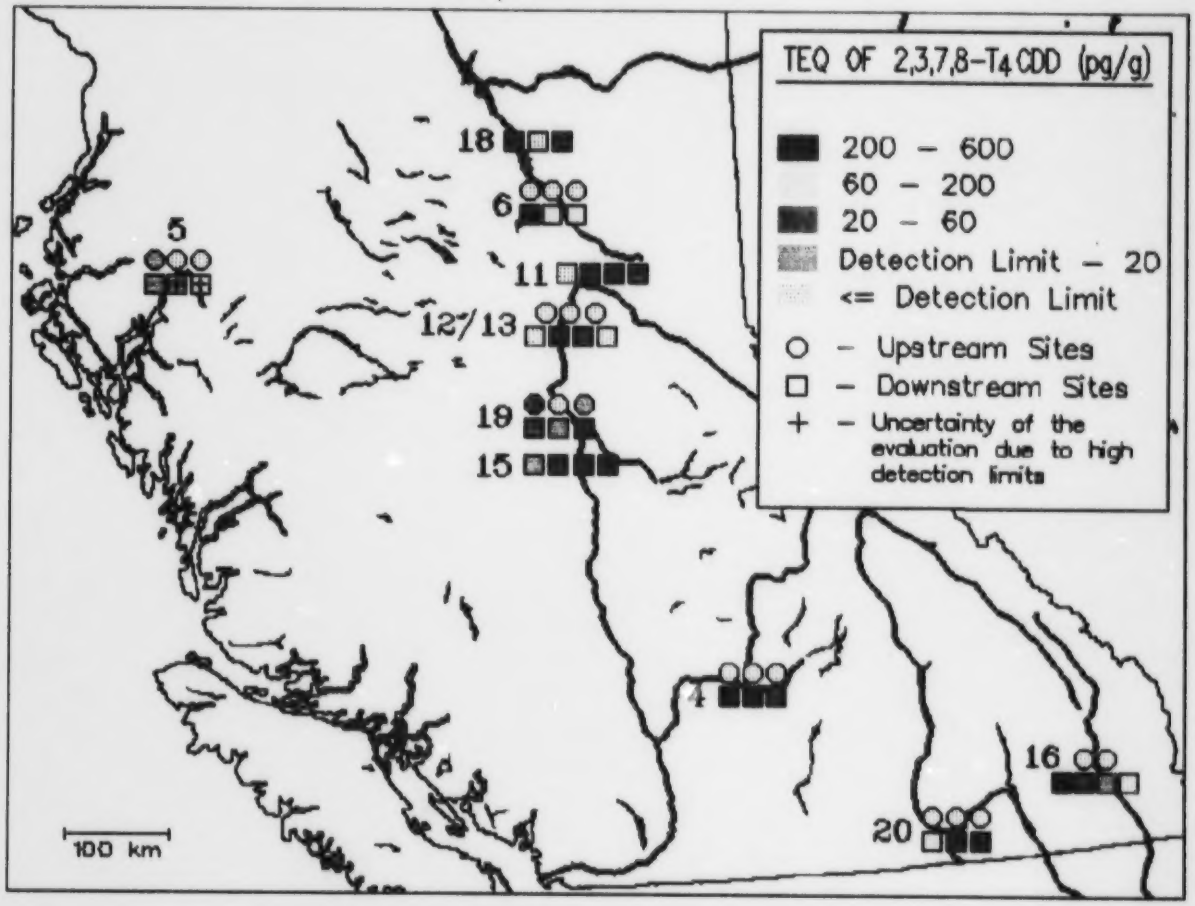
- Site #5F (Eurocan, Kitimat - control mill/no chlorine bleaching) is characterized by the presence of H_6CDD. This congener group is mainly absent from all other B.C inland sites. The use of contaminated wood chips is a possible explanation for the presence of H_6CDD in sediments.

- The 2,3,7,8-T_4CDF is largely predominant in the downstream sites, contributing to nearly 100% of the TEQs (see examples in Figure 8b).

Figure 6b

Sediment Contamination Expressed as 2,3,7,8 - T_4CDD Equivalents (pg/g)

British Columbia - Inland Sites



4. Weyerhaeuser Canada Ltd. – Kamloops
5. Eurocan Pulp & Paper Ltd. – Kitimat *
6. Fletcher Challenge Canada Ltd. – Mackenzie
11. Northwood Pulp & Timber Ltd. – Pringe George
12/13. Canfor Prince George Pulp & Paper and Prince George Pulp & Intercontinental Pulp Ltd. – Prince George
15. Cariboo Pulp & Paper Company – Quesnel
16. Crestbrook Forest Industries Ltd. – Cranbrook
18. [illegible] *
19. [illegible] *
20. Celgar Pulp Company – Castelgar

* Control Mill – No Chlorine Bleaching

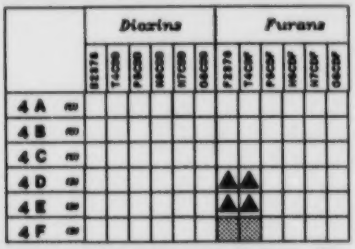
Figure 7b

CLASSIFICATION OF CONTAMINATION LEVELS

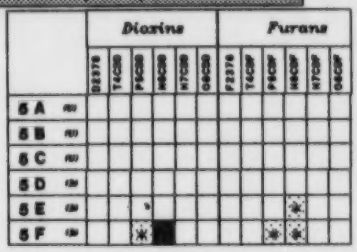
(See legend on page 63 for class limits)

British Colombia - Inland Sites

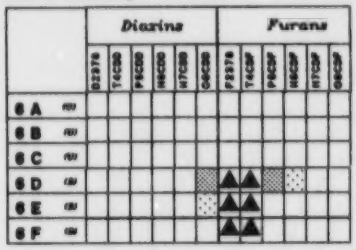
4. Weyerhaeuser Canada Ltd. - Kamloops



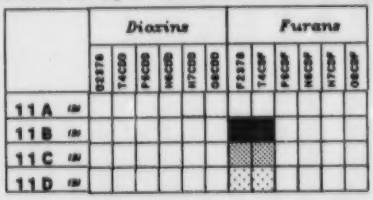
5. Eurocan Pulp & Paper Ltd. - Kitimat (2)



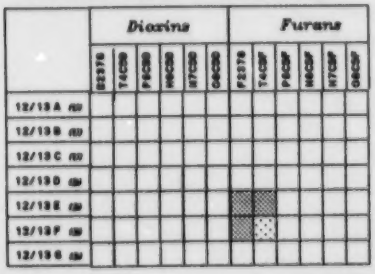
6. Fletcher Challenge Canada Ltd. - Mackenzie



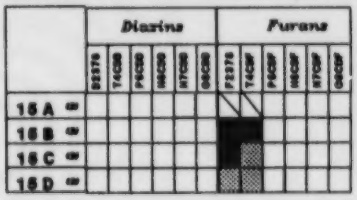
11. Northwood Pulp & Timber Ltd. - Prince George



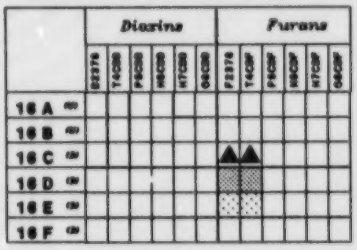
12/13. Canfor Prince George Pulp & Paper and Prince George Pulp & Inter-continental Pulp Ltd. - Prince George



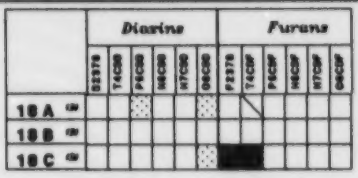
15. Cariboo Pulp & Paper Company - Quesnel



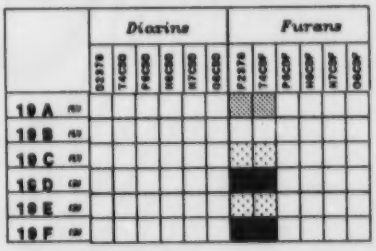
16. Crestbrook Forest Industries Ltd. - Cranbrook



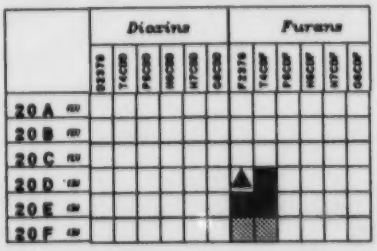
18. Finlay Forest Industries Ltd. - Mackenzie (2)



19. Quesnel River Pulp Co. Ltd. - Quesnel (2)



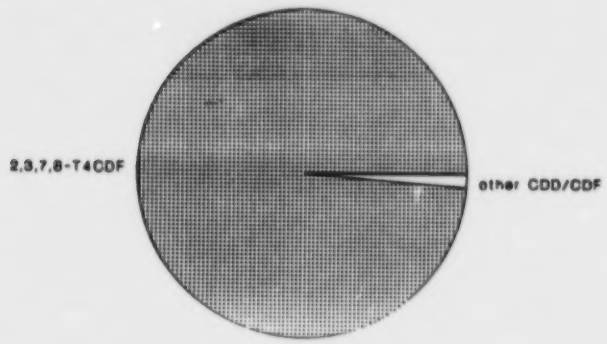
20. Celgar Pulp Company - Castelgar



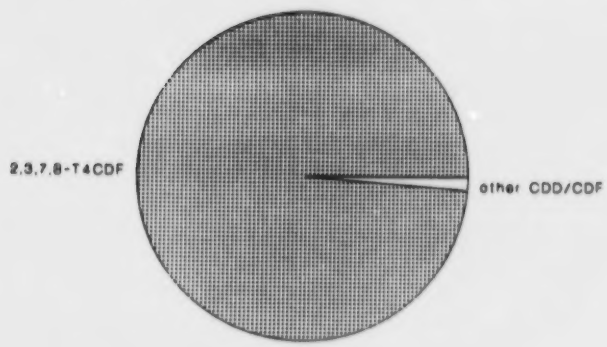
✳ - Uncertainty due to high detection limits

(2) - No Chlorine Bleaching

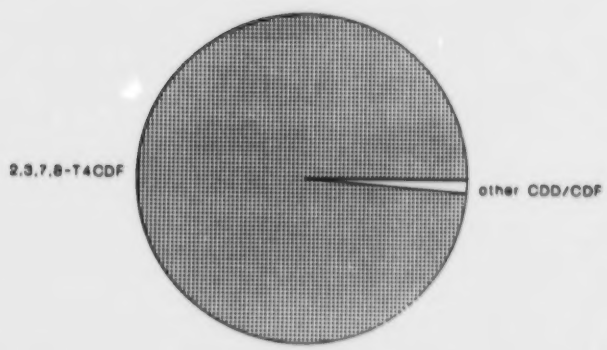
FIGURE 8b. RELATIVE CONTRIBUTION OF CONGENER GROUPS TO THE TEQs AT SELECTED INLAND SAMPLING SITES - BRITISH COLUMBIA



Site 4D



Site 6D



Site 16C

PRAIRIE REGION

Sediments collected around the three bleaching mills in the Prairies showed only "slight" levels of contamination in terms of TEQs (all sites less than 20 pg/g TEQs) and in terms of congener group concentration (Figure 6c and Figure 7c). Contamination in Wapiti River sediments collected at site #21B (Proctor and Gamble Cellulose) indicated the presence of 2,3,7,8-T_4CDF (36 pg/g) in "slight" concentrations.

Taking into account the very low number of samples collected in this region, it is difficult to interpret the presence of dioxins (P_5CDD, H_6CDD and O_8CDD) which were found at low levels in some of the samples (#22B, #23A, #24A).

The findings regarding slight contamination of sediments downstream of mill #21 and #22 appear to be consistent with those for samples collected in 1987, one year earlier (Alberta Environment, 1988). Sediment contamination at site #23 cannot be attributed to the pulp mill alone. Pentachlorophenol discharges from the city sever were observed (Saskatchevan Government, Department of Environment and Public Safety, News Release 89-066, February 2, 1989)[1]. There was no upstream control site.

Site #24A upstream of Manfor Ltd, which is a control site with no chlorine bleaching, falls into the "intermediate" class (20-60 pg/g TEQs - Figure 6c). It is dominated by P_5CDD, which is the major contributor to the TEQs evaluation, representing a high toxicity equivalent factor (Table 3).

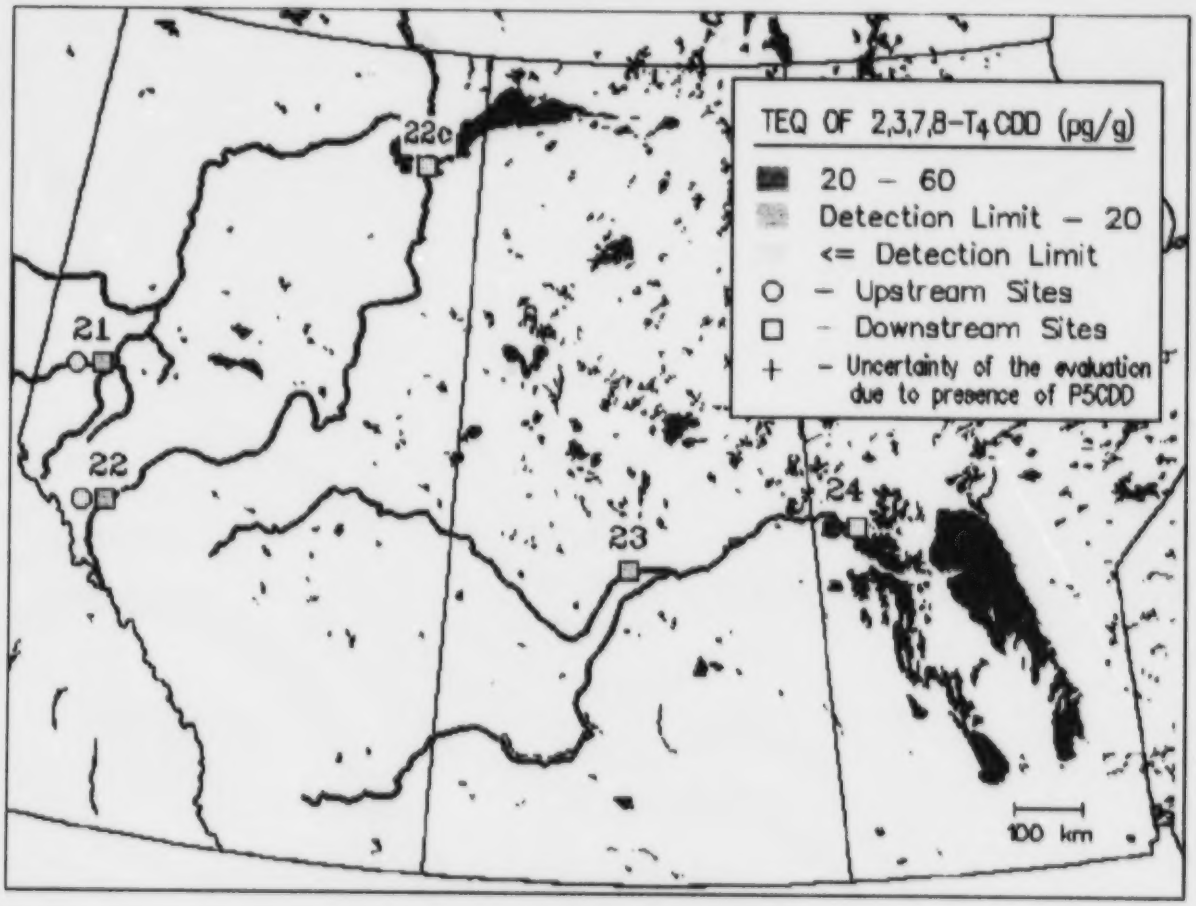
Contamination of upsteam site #24A is unexplained. The influence of discharge from the upstream Weyerhaeuser Canada Ltd. mill (mill #23) cannot be related to this contamination considering distance and hydrological factors (dams on the river upstream of site #24). Contamination of site #24A could be related to local sources and to the location of the site (site near a bridge pier). Additional sampling is required to confirm and elucidate contamination levels and sources at this site.

(1) Reference corrected on April the 10th, 1991

Figure 6c

Sediment Contamination Expressed as 2,3,7,8 - T_4CDD Equivalents (pg/g)

Prairie Provinces - Inland Sites



21. Proctor and Gamble Cellulose Ltd. – Grande Prairie, Alberta

22. Weldwood of Canada Ltd. – Hinton, Alberta

23. Weyerhaeuser Canada Ltd. – Prince Albert, Saskatchewan

24. Manfor Ltd. (Repap) – The Pas, Manitoba *

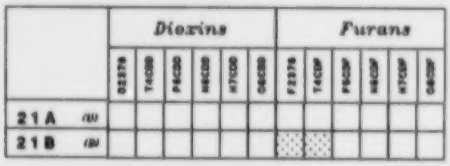
* Control Mill – No Chlorine Bleaching

Figure 7c

CLASSIFICATION OF CONTAMINATION LEVELS
(See legend on page 63 for class limits)

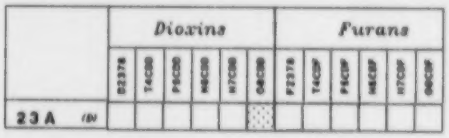
Prairie Provinces - Inland Sites

21. Proctor & Gamble Cellulose Ltd. - Grande Prairie, Alberta



22. Weldwood of Canada Ltd. - Hinton, Alberta

23. Weyerhaeuser Canada Ltd. - Prince Albert, Saskatchewan



24. Manfor Ltd. - The Pas, Manitoba ✳

✳ No Chlorine Bleaching

ONTARIO

Sediments collected close to five of the ten bleach mills in Ontario are "highly" (60-200 pg/g TEQs) to "very highly" (200-600 pg/g TEQs) contaminated. As opposed to the simple contamination patterns observed previously for inland mills (B.C. and the Prairies), sediment contamination around Ontario mills is much more complex to evaluate. Figures 6d and 7d illustrate well the discrepancies in contamination levels and characteristics between the sites.

- Contamination of Ontario sediments is distinguished from other inland mills by the presence of many CDD and CDF congener groups in "high" concentrations (Figure 7d).

- As illustrated in Figure 8c, the 2,3,7,8-T_4CDF is the predominant contributor to TEQ at site #26 C (C.P. Forest Products, Clay Lake).

- At sites #30 A, B, C (Domtar, Red Rock) TEQ are based on "very high" concentrations of H_6CDD, H_7CDD and O_8CDD (Figure 7d and 8c). Concentrations of these chlorinated dioxins are the highest observed in the survey. At these sites, hovever, lov concentrations of 2,3,7,8-T_4CDF are present in sediments. It must be noted that samples #30 A, B, C vere collected in 1986 and #30 D, E, F collected in 1989. It would appeared that contamination levels significantly decreased during that period of time. Interpretation of sediment characteristics (section 4.2 and Appendix I - organic carbon content) might also help in explaining these differences.

- At site #25B (Domtar, St.Lavrence River) H_6CDF is the major contributor to the TEQ (Figure 8c).

- Data are missing for site #28 (Boise Cascade Canada); the information is incomplete because of partial analysis. Hovever, 2,3,7,8-T_4CDD was detected at site #28E (8 pg/g - lover than the limit of quantitation <15 pg/g); 2,3,7,8-T_4CDF was not detected in sediments collected.

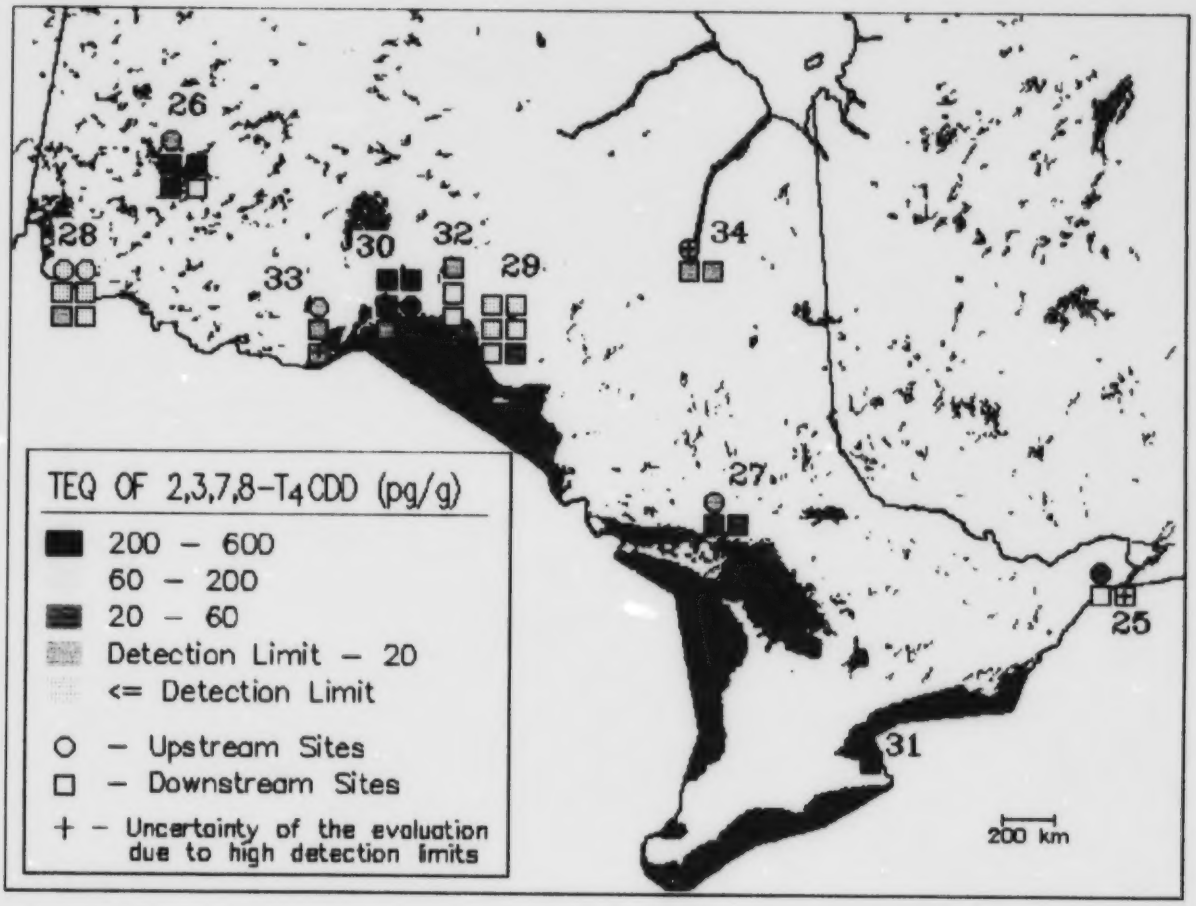
- At site #29 (James River Marathon, Superior Lake), samples collected on the opposite side of the peninsula (#29 E and F) vere contaminated, although the sample sites were located outside of the zone of effluent discharge. This might be explained by historical information regarding effluent location or by the presence of other sources or discharges secondary effluent in this area.

- The presence of 2,3,7,8-T_4CDD in sediments collected at sites #32 B and C (Kimberly Clark of Canada, Lake Superior) and site #26C (C.P Forest Products, Clay Lake) is observed at concentrations of 61, 67 and 66 pg/g respectively. The highest concentrations of 2,3,7,8-T_4CDF in Ontario sites vere found at sites #26C and #32C.

Figure 6d

Sediment Contamination Expressed as 2,3,7,8 - T_4CDD Equivalents (pg/g)

Ontario - Inland Sites



25. Domtar Inc. – Cornwall
26. C. P. Forest Products Ltd. – Dryden
27. E.B. Eddy Forest Products Ltd. – Espanola
28. Boise Cascade Canada – Fort Frances
29. James River Marathon Ltd. – Marathon
30. Domtar Inc. – Red Rock
31. Fraser Inc. – Thorold
32. Kimberly Clark of Canada Ltd. – Terrace Bay
33. C.P. Forest Products Ltd. – Thunder Bay
34. Malette Kraft Pulp and Power – Smooth Rock Falls

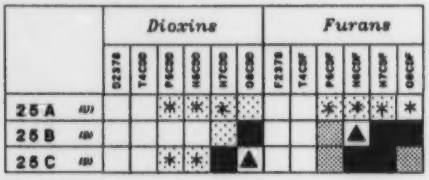
Figure 7d

CLASSIFICATION OF CONTAMINATION LEVELS

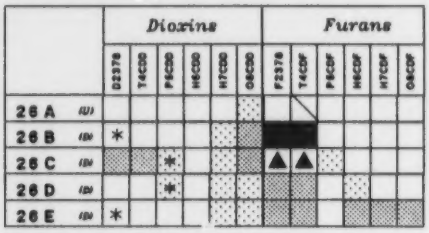
(See legend on page 63 for class limits)

Ontario - Inland Sites

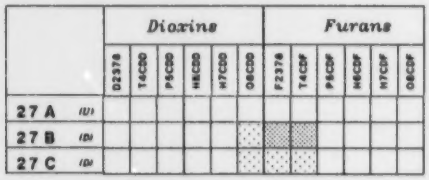
25. Domtar Inc. - Cornwall



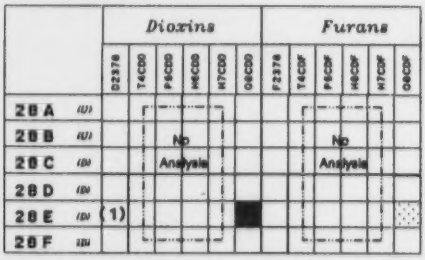
26. C. P. Forest Products Ltd. - Dryden



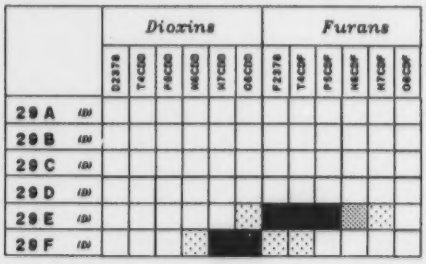
27. E.B. Eddy Forest Products Ltd. - Espanola



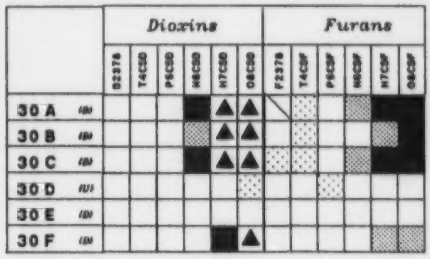
28. Boise Cascade Canada - Fort Frances



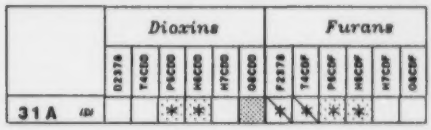
29. James River Marathon Ltd. - Marathon



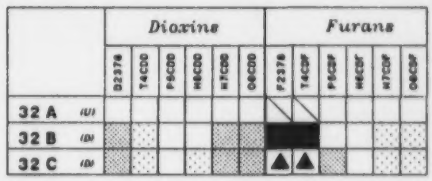
30. Domtar Inc. - Red Rock



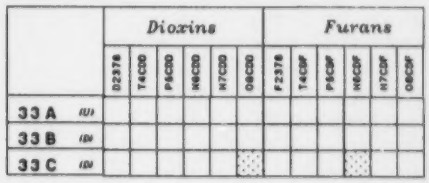
31. Fraser Inc. - Thorold



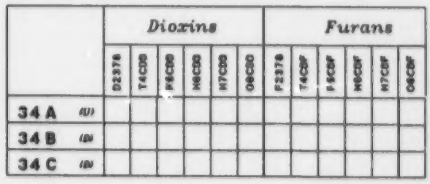
32. Kimberly Clark of Canada Ltd. - Terrace Bay



33. C.P. Forest Products Ltd. - Thunder Bay



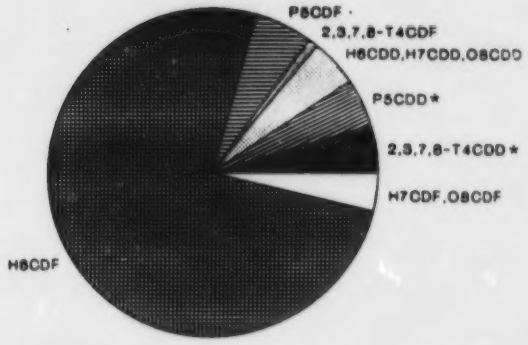
34. Malette Kraft Pulp and Power - Smooth Rock Falls



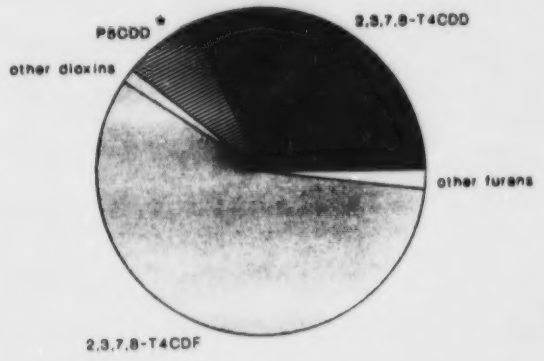
* - Uncertainty due to high detection limits

(1) - Detected at < 15 pg/g

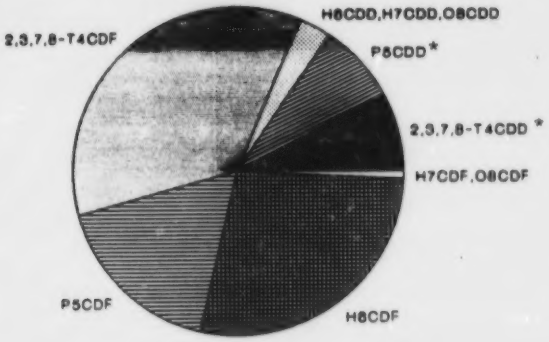
FIGURE 8c. RELATIVE CONTRIBUTION OF CONGENER GROUPS TO THE TEQs AT SELECTED INLAND SAMPLING SITES - ONTARIO



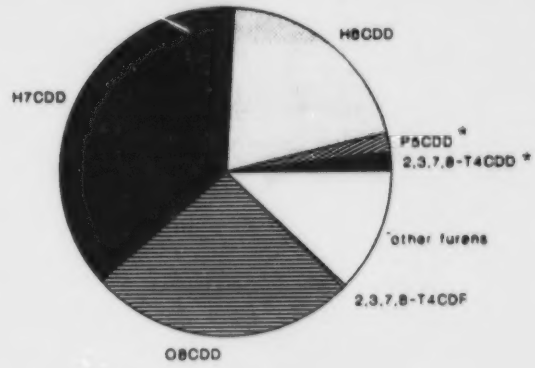
Site 25B



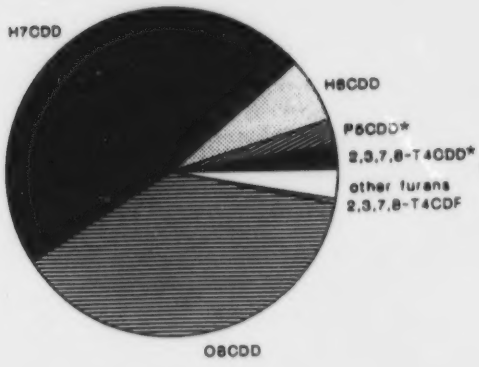
Site 26C



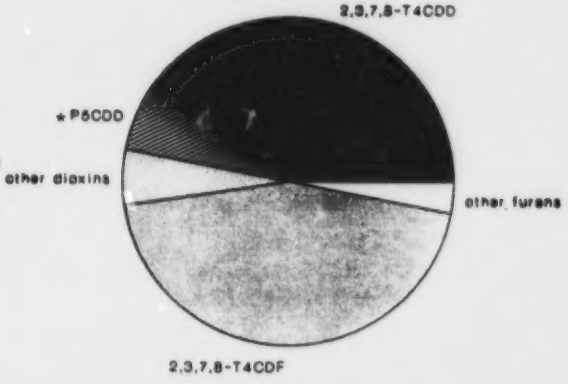
Site 29E



Site 30A



Site 30B



Site 32C

*Value less than detection limit: the assigned value is used in the pie chart

QUEBEC

Except for site #38, sediments at Québec mills do not show high concentrations of any of the dioxins or furans. In general, TEQs were in the "intermediate" or "slight" contamination levels (<60 pg/g TEQs). Examination of Figures 6e and 7e reveal discernible characteristics for only three of the nine mills:

- Sediments collected at site #38 (Produits des Pâtes et Papiers Domtar, Lebel-sur-Quévillon) were contaminated by 2,3,7,8-T_4CDD (43 pg/g), and 2,3,7,8-T_4CDF. Pentachlorodibenzofuran was also present. The 2,3,7,8-T_4CDD constitutes the major contribution to the TEQ (Figure 8d).

- Sediments from site #37 on the Saint-Maurice River (Produits Forestiers Canadien Pacifique, La Tuque) appeared to be contaminated by 2,3,7,8-T_4CDF, the major contributor to TEQ, and by highly chlorinated dioxin (H_7CDD and O_8CDD). Concentrations of 2,3,7,8-T_4CDD lower than the limit of quantitation (<15 pg/g) were measured. An in-depth environmental study conducted by the National Water Research Institute and Fisheries and Oceans will supply additional data to evaluate contamination levels at this site.

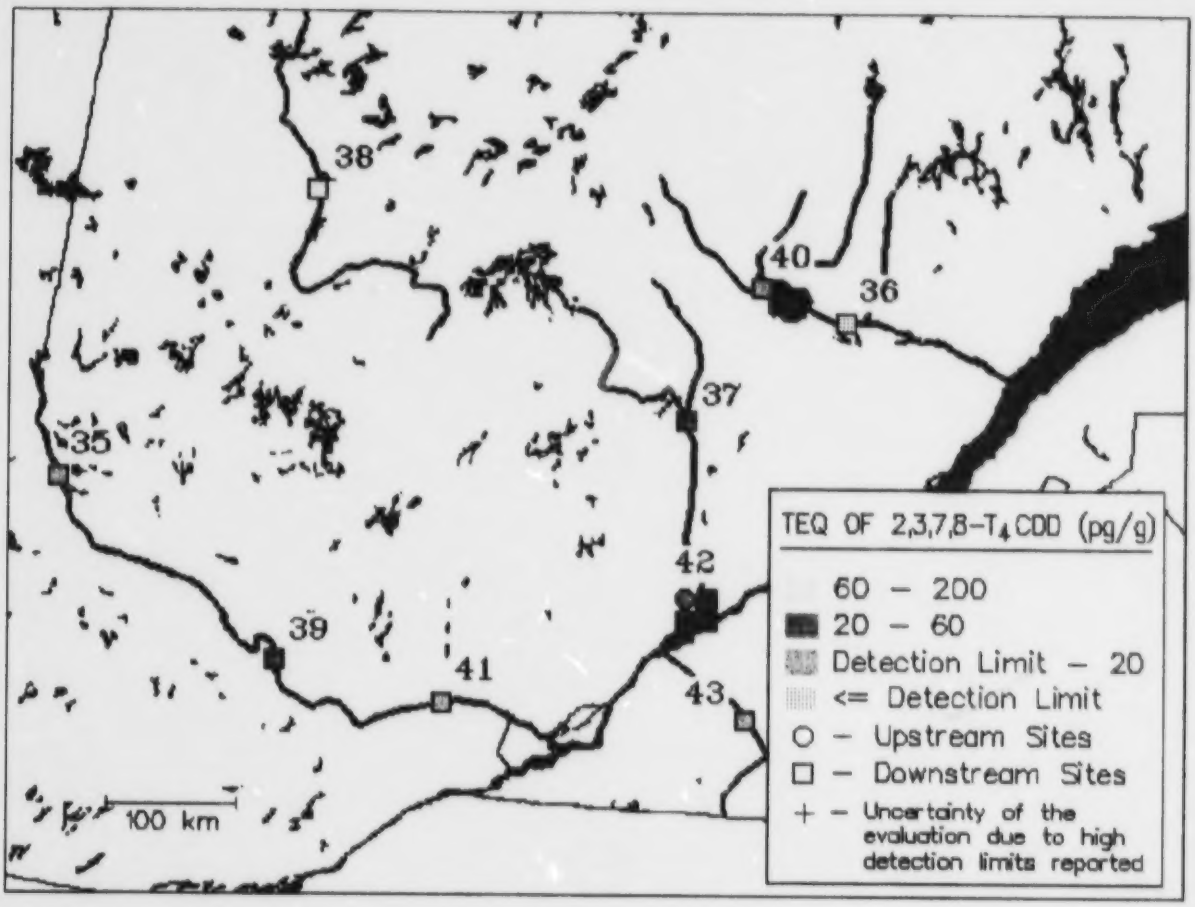
- At site #39 on Ottawa River at Portage-du-Fort, the TEQ value (21 pg/g TEQs) is very close to the "slight" contamination class (<20 pg/g TEQs). Since only one sample is available, the level of contamination can not be confirmed.

Here again, as indicated for the Prairies, the low number of samples impaired interpretation.

Figures 6e

Sediment Contamination Expressed as 2,3,7,8 - T_4CDD Equivalents (pg/g)

Quebec - Inland Sites



35. Tembec Inc. – Témiscaming
36. Cascades Inc. – Jonquière
37. Les Produits Forestiers Canadiens Pacifique Ltée. – La Tuque
38. Produits des Pâtes et Papiers Domtar – Lebel-sur-Quévillon
39. Stone Consolidated Inc. – Portage-du-Fort
40. Donohue St-Félicien Inc. – St-Félicien
41. Industries James MacLaren Inc. – Thurso
42. Stone Consolidated Inc. – Trois Rivières
43. Les Papiers Fins Domtar – Windsor

Figure 7e

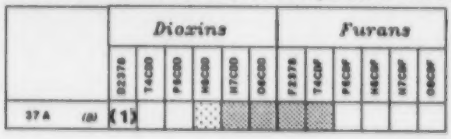
CLASSIFICATION OF CONTAMINATION LEVELS
(See legend on page 63 for class limits)

Quebec - Inland Sites

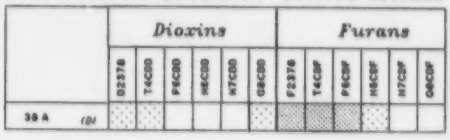
38. Tembec Inc. - Témiscaming

36. Cascades Inc. - Jonquière

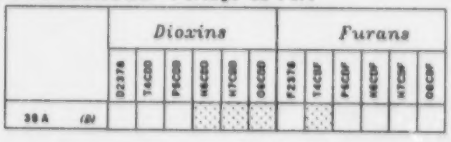
37. Les Produites Forestiers Canadiens Pacifique Ltée. - La Tuque



38. Produits des Pâtes et Papier Domtar - Lebel sur Quévillon



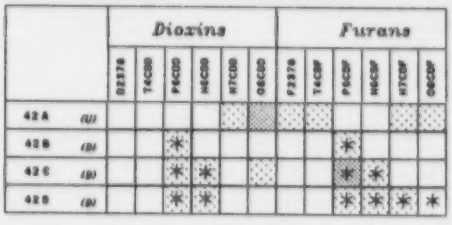
39. Stone Consolidated Inc. - Portage-du-Fort



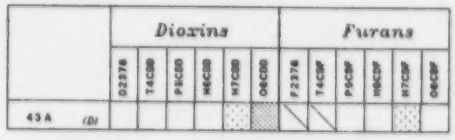
40. Donohue St-Félicien Inc. - St-Félicien

41. Industries James MacLaren Inc. - Thurso

42. Stone Consolidated Inc. - Trois Rivières



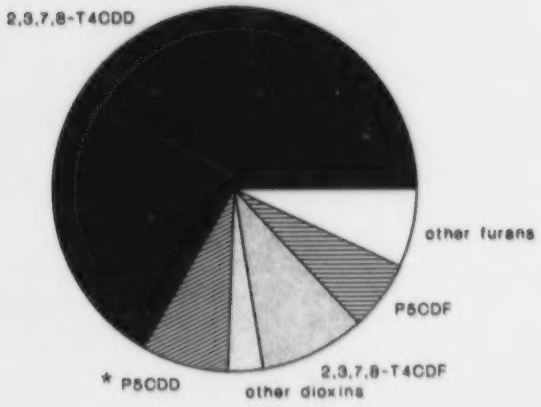
43. Les Papiers Fins Domtar - Windsor



* - Uncertainty due to high detection limits

(1) - Detected at < 15 pg/g

FIGURE 8d. RELATIVE CONTRIBUTION OF CONGENER GROUPS TO THE TEQs AT SELECTED INLAND SAMPLING SITES - QUEBEC



Site 38A

*Value less than detection limit: the assigned value is used in the pie chart

NEW BRUNSWICK

Dioxin and furan concentration at New Brunswick sites are in the "slight" and "intermediate" classes (<60 pg/g TEQs). An examination of the data on the contamination of sediments collected near New Brunswick mills (Figures 6f and 7f) led to the following comments:

- Sites #46 (Irving Pulp and Paper), #47 (Atholville Pulp) and #48 (Frasers) indicate "slight" contamination by H_7CDD and O_8CDD.

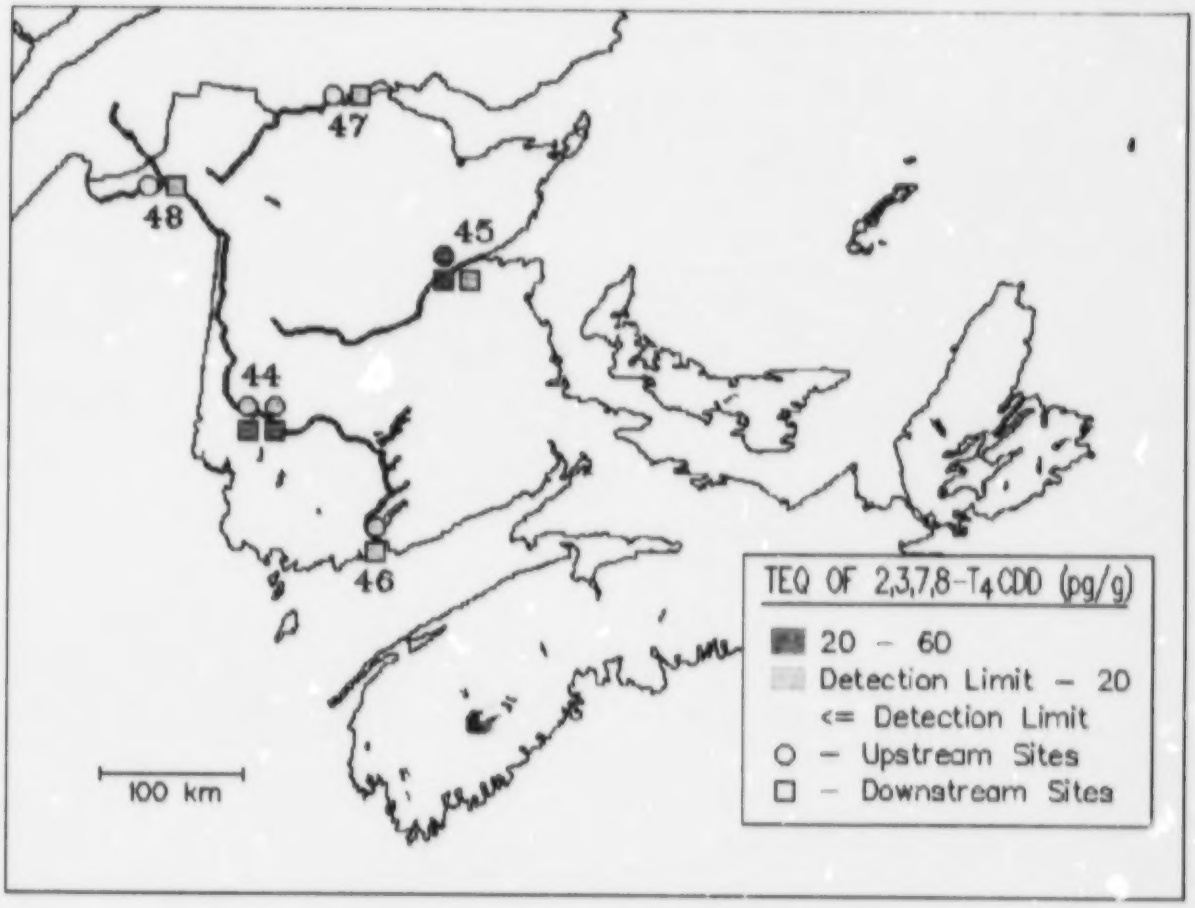
- Site #45 (Miramichi Pulp and Paper) is distinguished by very high concentrations of O_8CDD and the presence of high levels of contamination by 2,3,7,8-T_4CDF. Upstream site #45A is under tidal influence and therefore high contamination of sediments compared to downstream sites may be related to the transport of suspended sediments.

- Downstream site #44 shows evidence of "very high" concentration of H_7CDD and O_8CDD. On the other hand 2,3,7,8-T_4CDF was barely detected. Contamination of upstream sites (#44 A and B) is unexplained. The influence of discharge from the upstream Fraser Inc. mill (mill #48) cannot be assessed due to the limitations of the study design.

Figure 6f

Sediment Contamination Expressed as 2,3,7,8 - T_4CDD Equivalents (pg/g)

New Brunswick - Inland Sites



44. St. Anne–Nackawic Pulp & Paper Ltd. – Nackawic

45. Miramichi Pulp & Paper – Newcastle

46. Irving Pulp & Paper Ltd. – Saint John

47. Atholville Pulp Inc. – Atholville

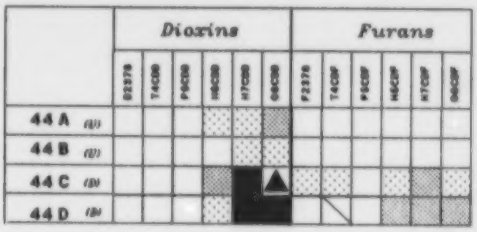
48. Frasers Inc. – Edmundston

Figure 7f

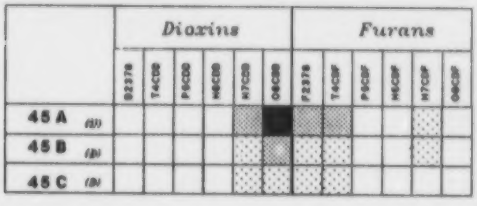
CLASSIFICATION OF CONTAMINATION LEVELS
(See legend on page 63 for class limits)

New Brunswick - Inland Sites

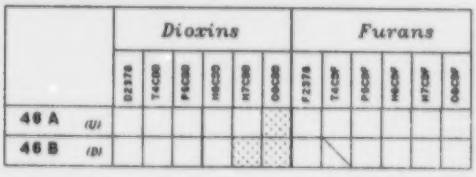
44. St. Anne-Nackawic Pulp & Paper Ltd. - Nackawic



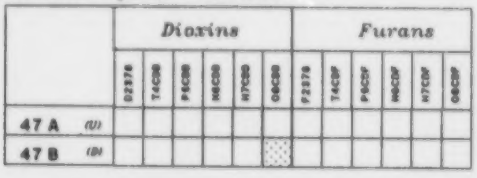
45. Miramichi Pulp & Paper - Newcastle



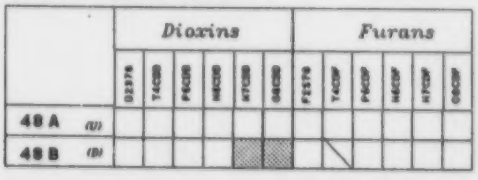
46. Irving Pulp & Paper Ltd. - Saint John



47. Atholville Pulp Inc. - Atholville



48. Fraser Inc. - Edmundston



LEGEND

CLASSIFICATION OF CONTAMINATION LEVELS
INLAND SITES

Legend

Classification of Contamination Levels

Inland Sites

‹ Detection Limit | Low or Slight | Intermediate | High | Very High | Highest

Dioxins		*Furans*	
CONGENERS	CONCENTRATIONS (pg/g)	CONGENERS	CONCENTRATIONS (pg/g)
D2378 (2,3,7,8-T4CDD)	‹= 15 No Class(1) 15 - 45 45 - 150	F2378 (2,3,7,8-T4CDF)	‹= 10 10 - 15 15 - 45 45 - 150 150 - 450 450 - 3,200
T4CDD	‹= 15 No Class(1) 15 - 45 45 - 150	T4CDF	‹= 10 10 - 25 25 - 75 75 - 250 250 - 750 750 - 4,500
P5CDD	‹= 20 No Class(1) 20 - 60	P5CDF	‹= 15 No Class(1) 15 - 45 45 - 150 150 - 450
H6CDD	‹= 30 No Class(1) 30 - 90 90 - 300 300 - 900	H6CDF	‹= 25 No Class(1) 25 - 75 75 - 250 250 - 750 ›750
H7CDD	‹= 50 No Class(1) 50 - 150 150 - 500 500 - 1,500 › 1,500	H7CDF	‹= 40 No Class(1) 40 - 120 120 - 400 400 - 1,200
O8CDD	‹= 75 No Class(1) 75 - 225 225 - 750 750 - 2,250 › 2,250	O8CDF	‹= 75 No Class(1) 75 - 225 225 - 750 750 - 2,250

(1) - When the median is equal to the detection limit a "low or slight" contamination class is not created

4.2 PARTICLE SIZE AND ORGANIC CARBON CONTENT

Particle size distribution and organic carbon content are two important sediment characteristics which were determined in all samples. Results are presented in Appendix I-1 and graphs in Appendix I-2. Particle size distribution was categorized according to the following (Horovitz, 1985; Environment Canada, 1988):

Clay	<0.004 mm
Silt	0.004 - 0.062 mm
Sand	0.062 - 2 mm
Gravel	>2 mm

Summary characteristics for inland and coastal sediments are presented in Table 6.

It is recommended that grain size and total organic carbon are measured when determining contamination of sediments by toxic organics with low water solubility (hydrophobic compounds) since these two factors are known to affect contaminant concentrations. Silts and clays are known to adsorb contaminants.

Two useful groupings can be made - coarse and fine (IJC, 1988). The coarse group (sands and gravel >.062 millimeters in diameter) is composed primarily of stable, inert, inorganic, silicate minerals with the shapes of individual particles tending toward equidimensional or spherical. Coarse sediments are not associated with contaminants usually, but may be in contaminated areas.

The fine group, silts and clays (<.062 mm), is significantly different (IJC, 1988; Horovitz, 1985). Samples usually are found to consist largely of clay-sized materials, whose layered open structure results in large surface-area-to-mass ratios. Because of their small size, electrical charge characteristics and large surface area, they can remain in suspension for long periods. These particles are also characterized by unbalanced surface electrical charges, which causes them to flocculate and settle out of suspension as composite grains. Their fine texture and large surface area make them much more chemically and biologically reactive than the coarser materials and provide adsorption sites for a variety of contaminants. These properties of the fine sediments explain why they usually comprise the bulk of the contaminated sediments.

In addition to particle size, organic carbon content was also determined, since it may play an important role in the sorption processes of toxic organic contaminants onto particles (Allan, 1985, Elzerman and Coates, 1987). Hydrophobic compounds are adsorbed to finer particles. Differences in sorption within clay and silt are

Table 6. Summary of Sediment Characteristics

	Organic Carbon (%)	Clay (%)	Fine* (%)
	INLAND SITES		
Minimum	0.03	0.0	0.1
Maximum	32.9	50.0	98.5
Median	1.9	6.2	40.5
Mean	3.8	9.3	42.8
SD	5.5	9.9	29.5
No. of samples	117	119	119
	COASTAL SITES		
Minimum	0.06	0.0	0.4
Maximum	9.5	41.8	74.0
Median	1.6	2.0	10.5
Mean	3.1	7.5	27.3
SD	3.1	12.7	27.9
No. of samples	27	20	20

*Fine included sum of clay and silt particles

SD Standard Deviation

related to their organic carbon content (Karichkoff et al. 1979). Numerous physical and chemical factors (composition, surface area, surface charge, complexation, etc.) affect a sediment's capacity to collect and concentrate toxic organic contaminants: these complex processes make predictions difficult (Allan, 1985).

The relationship between particle size, organic carbon content and concentration of dioxins and furans were investigated.

Theoretically, it can be assumed that sediment characteristics (such as surface area and organic carbon content) correlate significantly with contaminant sorption by sediments. However, this relationship is not supported in this study. The concentrations of dioxins and furans measured in downstream and coastal sediment samples do not correlate significantly with organic carbon content or with percent clay plus silt fractions found in the samples. Based on correlation analysis of non-transformed data, correlation values were low ($r<0.4$ in each of the twelve regressions). The scatterplots of sediment characteristics versus concentrations of dioxins and furans are shown in Appendix I-3.

We concluded that geographical factors (site locations, hydrological and ambient conditions) and differences in contaminant sources rather than sediment characteristics were more significant considerations in the explanation of the variation observed in dioxin and furan concentrations.

Data can be interpreted based on the above theoretical assumption of correlation between fine fractions (clay and silt) and dioxin/furan concentrations in the sample. This means that a sediment sample with a low percentage of fine fractions would not be adequate to determine with certainty the level of contamination by dioxins and furans. In such cases, going back to the sampling site to collect new samples, with higher proportions of fine fractions, may reveal higher concentrations of dioxins and furans.

The following discussion suggests different hypothetical scenarios regarding particle size distribution for the interpretation of contamination levels.

1) **Contamination is "not detected" or the level of contamination is "slight" and fine particles are in low proportion (<20%).**

   In this scenario, contamination might exist but would not have been revealed due to inadequate sample characteristics (insufficient proportion of fine fraction). For example, the river reach sampled might occupy an actively eroding channel with high sediment transport capability, or sampling sites are located downstream of a dam where the upstream fine sediment load is being trapped.

The above scenario can be applied to the following locations:

- .#1 Fletcher Challenge (Campbell River, B.C.)
- .#34 Malette Kraft (Smooth Rock Falls, Ont.)
- .#35 Tembec (Témiscaming, Qué.)
- .#41 Ind. James MacLaren (Thurso, Qué.)
- .#49 Scott Maritimes (New Glasgow, N.S.)

As a priority, additional sampling has to be done to confirm the absence of sediment contamination. Even though the survey failed to detect contamination, it is recommended that bottom sediments should be thoroughly surveyed to locate depositional zones containing fine particles and that additional contaminant analysis be performed for these mills.

2) **Contamination is "not detected" or level of contamination is "slight" and fine particles are present in the sample in greater proportion (>20%).**

In these cases, interpretation of results is not definitive. A better understanding of site-specific hydraulic and geomorphological conditions is needed, and/or additional samples are required to confirm the results observed and contamination levels reported. Some factors, as described below, should be considered, or erroneous conclusions could be made.

Spring snowmelt, episodic high rainfall and water flow management at dams can cause erosion or resuspension of recent sediments in the area of deposition. Sediment samples collected might not be representative of the recent contamination history. Bed surficial materials can be exposed to scouring action and sediment transport/movement. Fine particles can also be collected in an area where degradation processes occur. Also it must be ensured that sampling sites were under effluent plume influence. Effects of dilution (distances from mills, tributary inputs, tidal section) must be taken into consideration.

These potential influences may affect the representativeness of the results. This, in addition to the low number of samples available per location, make interpretation difficult. Doubt persists regarding the validity of the results at certain sites.

The above scenario can be applied at the following sampling sites:

- .#21,#22,#23 Prairie pulp mills
- .#33 C.P. Forest Products (Thunder Bay, Ont.)
- .#36 Cascades (Jonquière, Qué.)
- .#40 Donohue (St-Félicien, Qué.)
- .#43 Les Papiers Fins Domtar (Windsor, Qué.)
- .#46 Irving P&P (Saint John, N.B.)
- .#47 Atholville P&P (Atholville, N.B.)
- .#48 Fraser (Edmundston, N.B.)
- .#50 Stora Forest (Port Hawkesbury, N.S.)

In the first two scenarios (16 sites), ve concluded that the extent of the available data base was insufficient to exclude the possibility of more highly contaminated areas elsevhere. Additionnal sampling is recommanded at these sites to complete the study's data. This is especially true in areas where surveys on fish and shellfish contamination have revealed the presence of dioxin and furan (Health and Welfare Canada, see Discussion, section 5.0).

3) **Levels of contamination of sediments are "intermediate", "high" or "very high" and fine particles are in low proportion (<20%).**

The existing contamination problem at sites yielding such results might be more acute than revealed by the present survey. If ve assume a direct correlation between fine particles and contamination levels, looking for areas vhere sediments are characterized by a higher percentage of fine particles could shov dioxin and furan concentrations higher than actually observed.

This situation appeared at the following locations:

- #3 C.P Forest Products (Gold River, B.C.)
- #4 Weyerhaeuser (Kamloops, B.C.)
- #7 MacMillan Bloedel (Nanaimo B.C.)
- #9 Canfor Products (Port Mellon, B.C.)
- #27 E.B. Eddy (Espanola, Ont.)
- #31 Fraser (Thorold, Ont)
- #42 Stone Consolidated (Trois-Rivières, Qué.)

Therefore, to obtain accurate sediment contamination data at these locations, further sampling and analytical work must be conducted. However, confirmation of these results are not considered as a priority compared to the above scenarios 1 and 2.

4) **Levels of contamination of sediments are "intermediate", "high" or "very high" and fine particles are in higher proportion (>20%).**

This scenario applies to 20 cases for which a higher confidence in the validity of the contamination data and interpretation is substantiated. These sites are: #2, #6, #11, #12/13, #14, #15, #16, #17, #20, #25, #26, #29, #30, #32, #37, #38, #39, #44, #45.

At site #8 - Port Alberni, site #10 - Powell River, site #28 - Fort France and site #51 - Port Alice, no results on particle size distribution are available. Detailed studies have been started in coastal British Columbia areas where fishery closures and health advisories were issued and will provide additional sediment results.

4.3 QUALITY ASSURANCE/QUALITY CONTROL

QA/QC data and an in depth assessment and interpretation of the results are presented in Appendix D. As indicated in the QA/QC discussion, interpretation of QA/QC results is limited by the following factors: inappropriate QC samples, inadequate spiking levels of reference material and insufficient data to document competency of participating laboratories. Consequently, the QA/QC results are considered only partly acceptable. The following statements address this component of the program:

1) For the QC samples containing lov levels of 2,3,7,8-T_4CDD, large differences in detection limits among laboratories and large discrepancies from the design value suggest that data provided by the commercial laboratories could be less accurate and not comparable in certain cases. At lov levels of 2,3,7,8-T_4CDF, accuracy and comparability indicate slightly better results but insufficient documentation precludes conclusion on the quality of these analyses.

2) At levels equal to or greater than 100 pg/g of 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF, the analytical performance of the laboratories is considered acceptable; good accuracy and comparability ($\pm$ 20%) of the results was obtained.

3) For the other congener groups of dioxins and furans (penta to octa chlorinated) interlaboratory variation ($\pm$ 50%) is greater and outlier values are more predominant.

It must be emphasized that QA/QC results have a large influence on data treatment and conclusions derived from the sediment program. QA/QC results and interpretation are appended (for convenience) to the core of the report. The reader is urged to consider the information in the section as it is a key element in the program.

5.0 DISCUSSION

The following discussion is offered as a help to the interpretation of the results.

QA/QC and Analytical Results

It has been recognized that QA/QC data for the actual survey were insufficient (section 4.3 and Appendix D) and permit only a partial confidence in the validity of the analytical results. The validity of the analysis of 2,3,7,8-T_4CDD at low levels (from detection limit to 50 pg/g) can not be assessed. As other QA/QC studies has shovn (Stokker and Chau 1990, NWRI, pers. comm.; Chiu and al. 1989), high variability occurs at low levels of 2,3,7,8-T_4CDD. Therefore, it would be irrelevant to attempt to differentiate contamination levels between sites or mills considering the range of values encountered in the study (detection limits to 67 pg/g of 2,3,7,8-T_4CDD).

Based on the limited actual knovledge on the extent of transfer of dioxin from sediments to aquatic biota, the acquisition of accurate and reliable data close to limits of detection is strongly recommended since safe level of sediment contamination for the aquatic ecosystem has not be determined.

Results shoved that sediments were not contaminated by 2,3,7,8-T_4CDD at levels greater than 100 pg/g. This observation is supported by more reliable QA/QC data. It must be remembered, when looking at results for the other dioxin and furan congeners, that QA/QC studies shoved that fluctuations of $\pm$50% in laboratory comparison were regularly observed.

The TEQ estimations reported in this report could have resulted in an overestimation and could be misleading. Calculations assumed that all dioxins and furans were 2,3,7,8-subtituted, i.e. the most toxic forms. Provisions should be made to obtain complete results on each congeners of the homologue series of dioxins and furans. Toxicity Equivalent estimations would be therefore more accurate.

Sampling Protocol and Design

It could be seen from the field reports completed by personnel in charge of sediment sampling (regional or provincial offices) that samples were not collected in a uniform way. Interpretation of the sampling protocol, time constraints and accessibility to the sites generated differences that could affect the quality of the data.

Some of the sampling was conducted in 1985, 1986 and 1987, prior to the formation of the Task Force on dioxins and the development of protocols. This makes very difficult the integration of the data in a report because the sampling approach used in all regions was not consistent.

In British Columbia (inland mills) the top 3 to 4 cm of sediment sample was retained. British Columbia completed its sampling before the protocols for the national dioxin survey was designated. In other regions (Atlantic region and Ontario Environment) the top 1 cm was taken as specified in the sampling protocol (it is assumed that the protocol was followed by the other regions as well). Particular attention should be given to sediment sampling depth. Sediments below the top 1 cm may be more or less uncontaminated since they represent a long period of accumulation and, depending on the volume homogenized, may in fact dilute more recent sediment concentration. This aspect can contribute significantly to a misinterpretation of the analytical results from site to site.

The sampling protocol specified collection and composition of three grab samples from each of the three sites, due in part to restrictions placed on the number of samples to be submitted for analysis. Differences occurred among the sample sets received from the regions. For example, in the Atlantic region, each sample represented three grab samples collected at each site. These differences can affect the representativeness of the results.

In the context of the constraints regarding the low number of samples that were submitted by the different regions, as they were instructed, it is evident that spatial variability and validity of contaminant levels cannot be evaluated from this study.

It must be understood that number of samples submitted in the regions (Atlantic, Quebec and Prairie) followed the instructions of the program design. An explanation for the disparities observed between regions, in terms of number of samples submitted for each mill (e.g. Ontario submitted one upstream sample and three downstream, Quebec submitted only one downstream sample) is beyond this report. But, sampling protocol and design certainly represent major limitations and difficulties in the achievement of the survey objective - to determine the presence or absence of sediment contamination. Representativeness of the results must be established and valid comparisons are essential. Not many conclusions can be drawn from one downstream sampling site.

Receiving Water Characteristics and Site Variability

Riverine, lacustrine and marine systems are affected by different factors that control the sedimentation process. The fate and transport of a chemical compound in the aquatic environment will be determined by the physical and chemical properties of the compound, characteristics of the receiving water and degradation mechanisms. Local site variations are determinant in the process, affecting both fate and transport of contaminants (NCASI, 1989).

Water circulation depends on winds, river floods, differences in salinity and density (mixing of freshwater and saltwater), tidal currents and the kind of suspended sediments being transported.

Coastal sites cover a variety of conditions with uneven bottom topography, surrounding channels and varying water depths resulting in tide and current patterns ranging from simple to complex. In marine and estuarine sites,

such parameters as tidal currents, freshvater flov inputs, local offshore currents, halocline (density differences), temperature differentials, landlocked configuration or differences in deeper and surface currents can have a tremendous impact on mixing and sediment transport. In rivers, the flov volume and the velocity affect load, mixing and transport of sediments and associated contaminants. River flov can vary dramatically between sites. It has been shovn that lakes trap many sediment particles in the lake bed.

The selection process for a representative sampling site thus requires a good knovledge of the specific characteristics of the system, without which erroneous conclusions on the state of contamination can be dravn.

Riverine transport of contaminants may be dominated by the suspended sediments. A study by Merriman (1988) on the Rainy River, in Ontario, to determine the presence of organic compounds (including dioxins and furans) both in the river and at the two pulp mill effluents (Boise Cascade Corporation) located in Fort France and International Falls (at the upstream end of the river) indicated, for the first time, 2,3,7,8-T_4CDD vas present in the Rainy River in a matrix other than fish. 2,3,7,8-T_4CDD vas found to be present in the suspended solids fraction at concentrations of up to 11.5 pg/g at 5 km dovnstream of the mills. O_8CDD vas found at concentrations of 149 pg/g and 42 pg/g at two sites dovnstream 5 km and 125 km respectively.

Under condition of high flov the precise sampling strategy for bed sediments requires careful planning, since only occasional sediment pockets may be found.

Sources of Dioxins and Furans

CDDs and CDFs are trace contaminants found in pentachlorophenol (PCP), used as a vood preservative, and are formed in pulp mills using the chlorine bleaching processes (Environment Canada, 1990). Pentachlorophenol formulations have been used in Canada for several decades to preserve lumber for export. The most potent source of CDDs in the British Columbia aquatic environment is chlorophenols (Elliot et al., 1988). Chlorophenols are known to contain a host of CDDs and CDFs (Hagenmaier and Brunner, 1987). Chlorophenol-contaminated vood chips have also been used in pulp mills.

Recent studies by the Pulp and Paper Research Institute of Canada (Berry et al.,1989) indicated that pulp made from PCP contaminated vood chips contains certain CDDs consisting predominantly of H_6CDD and some H_7CDD and O_8CDD. The studies also shoved that defoamers and vashing additives used in pulp mills could act as precursors for the formation of dioxins and furans. Chlorinated dioxins and furans result from chlorination of the

precursor molecules dibenzodioxin and dibenzofuran which have been identified in trace amounts in unbleached pulp (they can also occur from chemical reactions involving direct chlorination of lignin). In particular, 2,3,7,8-T_4CDD, 2,3,7,8-T_4CDF and 1,2,7,8-T_4CDD were identified as predominant species in pulp mill effluents and sludge (Berry et al., 1989).

The range of dioxin and furan levels from one mill to another varies as well as the degree of chlorination. Kraft pulp and paper mills are known to produce 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF in the chlorine bleaching process (Clement et al., 1989; Amendola et al., 1989; Kringstad and McKague et al., 1988). Ratios of 2,3,7,8 T_4CDF/2,3,7,8-T_4CDD were consistent within a certain mill, but the ratios were found to be highly variable from mill to mill. A common characteristic of these studies is the predominance of 2,3,7,8-T_4CDF often more than fivefold higher than 2,3,7,8-T_4CDD.

An effluent characterization of Canadian pulp mills using chlorine bleaching was conducted early in 1989 by the Canadian Pulp and Paper Mill Association under dioxin sampling. Dioxin and furan concentrations in composite effluent samples can be compared to the profile obtained from the sediment survey program. Discharge data corroborate some of the findings on sediment quality as follows:

- As indicated in Table 7, coastal and inland mills are differentiated mainly by contaminant loads; coastal mills introduce higher quantities of dioxins and furans into the aquatic environment than inland mills (total 7 300 g/y versus 1 390 g/y respectively). The sediment data reflect this trend.

Table 7. Total Mass (grams/years) of Dioxins and Furans in Pulp Mill Discharges (from CPPA, 1989).

Congeners	Coastal Mills	Inland Mills
2,3,7,8-T_4CDD	19.7	25.3
T_4CDD	257.7	25.3
P_5CDD	249.5	0.0
H_6CDD	3453.7	593.5
H_7CDD	207.0	167.6
O_8CDD	219.8	53.1
2,3,7,8-T_4CDF	1095.1	314.3
T_4CDF	1844.1	509.1
P_5CDF	53.2	3.1
H_6CDF	3.6	16.8
H_7CDF	311.4	9.9
O_8CDF	716.7	14.1
TOTAL	7300	1390

- In Figure 9, dioxins and furans are more frequently detected in coastal mill effluents than in inland mill effluents. Coastal mill effluents are contaminated by a mixture of CDD and CDF. Contamination levels of sediments and effluents shows similar frequencies of detection and trends.

- High frequencies of both low and highly chlorinated dioxins (particularly H_6CDD) in coastal mill effluents and sediments would indicate multiple sources of contamination (chlorophenols, contaminated wood chips and bleaching processes).

- As illustrated in Figure 10, the congener groups found predominantly in sediments do not correspond to those found in mill effluents. Distribution of dioxins and furans in sediments and effluents showed differences.

The previous comparative exercise using data obtained from effluent characterizations and sediment quality is valid only as an overview. Direct comparisons (site specific) of data obtained from the two parts of the program could lead to erroneous conclusions. Effluent data reflect a snapshot-type picture based on one survey. In some cases, data do not reflect the current levels of dioxins and furans because of process changes made since the time of the survey. Several mills have already installed technology and undertaken actions (reformulated defoamers, using uncontaminated wood chips) to clean up and control discharges of dioxins and furans and to reduce the amount of chlorine used in the processes. On the other hand sediment data may reflect a cumulative deposition of mill contaminants over many years or, in other cases, inappropriate sediment sampling might affect the representativeness of the results.

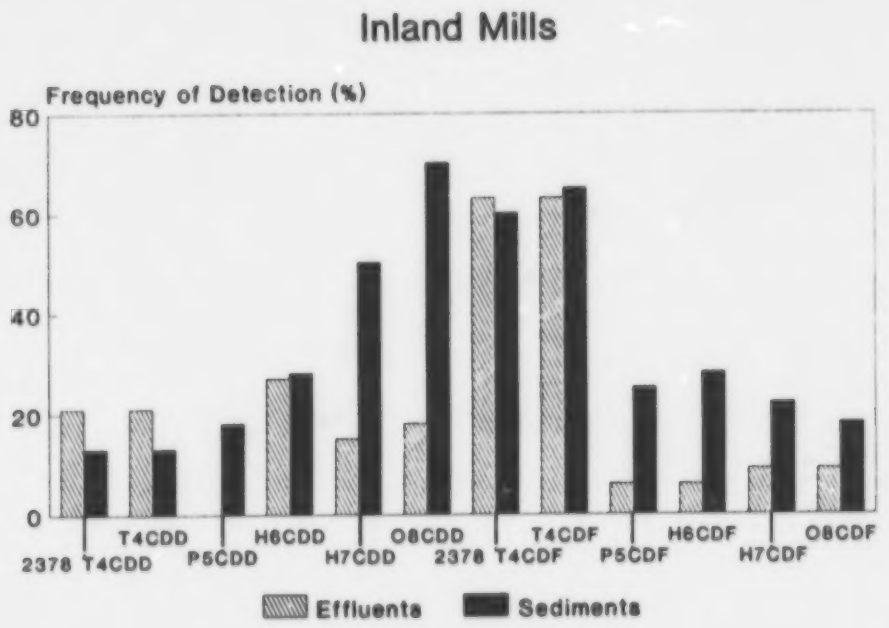
The following examples illustrate the above comments and suggest that the two parts of the program have appreciable limitations as a means of identifying contamination.

- At Campbell River (Fletcher Challenge Canada, B.C.) sediments showed low levels of 2,3,7,8-T_4CDF. However, effluent data indicated relatively important discharges of 2,3,7,8-T_4CDF and H_6CDD (among the highest ones).

- At New Glasgow (Scott Maritimes, Nova Scotia), the presence of 2,3,7,8-T_4CDF and O_8CDD in the effluents is not supported by sediment samples collected in Northumberland Strait.

- In Thurso, presence of H_6CDD in the effluent (Industries James MacLaren) is not supported by sediment data from the Ottawa River.

FIGURE 9. COMPARISON OF DIOXIN AND FURAN DETECTIONS IN PULP MILL EFFLUENTS AND SEDIMENTS



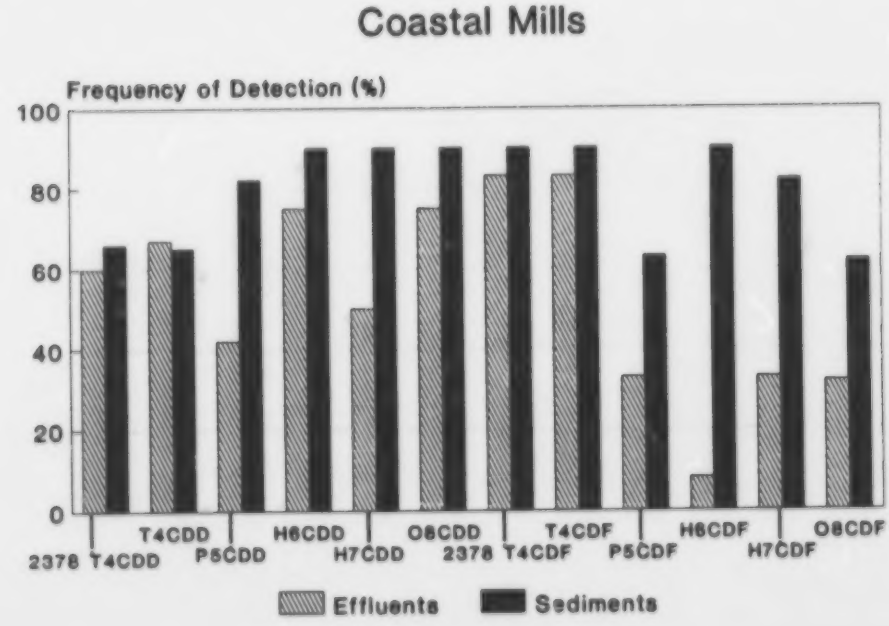
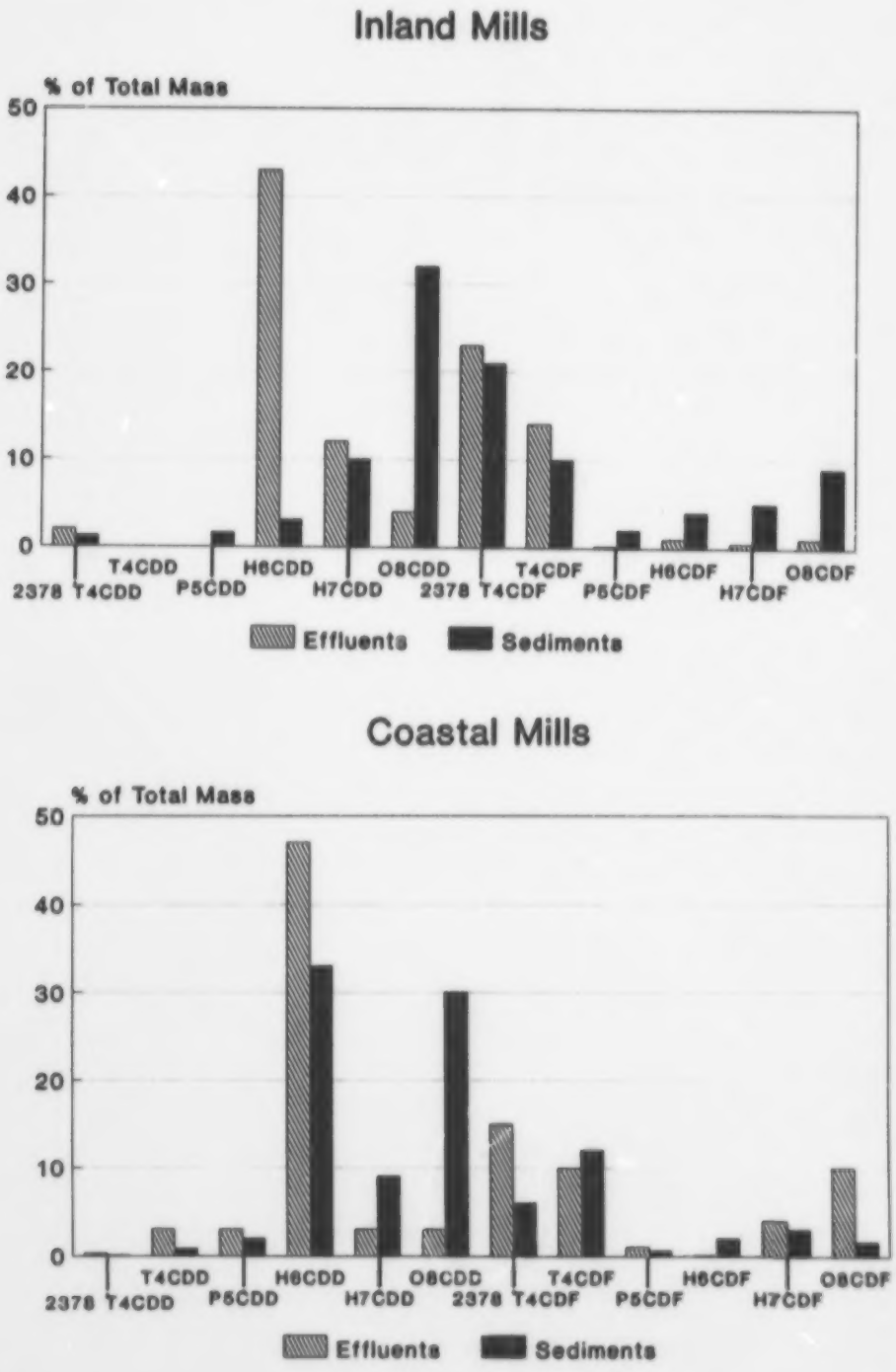


FIGURE 10. DISTRIBUTION OF DIOXIN AND PURAN CONTAMINATION IN PULP MILL EFFLUENTS AND SEDIMENTS



- Sediments collected near Kimberly Clark mill (Terrace Bay, Lake Superior) indicated a very high level of contamination in terms of TEQs along with a very high concentration of 2,3,7,8-T_4CDF and presence of 2,3,7,8-T_4CDD, H_7CDD, O_8CDD, P_5CDF, H_7CDF and O_8CDF. In the effluent, only 2,3,7,8-T_4CDF and O_8CDD were detected.

- At Cranbrook (Crestbrook Forest Industries, British Columbia), the TEQs in sediments collected in the Kootenay River are very high. None of the dioxin or furan congeners were detected in the effluents.

In conclusion, the absence of quantifiable levels of dioxins and furans in the effluent does not appear to be a guarantee of good sediment quality and absence of contamination. However, the presence of dioxins and furans in the effluent could be indicative of a potential sediment contamination problem even though no direct correlation between sediment quality and effluent concentrations can be made. In that respect it would be appropriate to conduct additionnal assessments at the following mill sites; #1, #21, #22, #23, #34, #36, #39, #40, #41, #43, #46.

Dioxins and Furans in Fish and Shellfish

The major portion of this part of the Dioxin Sampling Program is nov complete. Samples of fish, molluscs and/or crustaceans collected in the vinicity of all Canadian bleached kraft mills have been processed and sent to participating laboratories (Health and Welfare Canada, July 1989). Data on fish and shellfish contamination are available for British Columbia, Alberta, Manitoba, Saskatchevan and Québec. Samples for the Maritimes were revieved by Health and Welfare Canada. Sample for Québec are being prepared for submission to Health and Welfare Canada for reviev. The analysis of Ontario sample data is being performed. Further sampling is underway in B.C., Ontario, Québec, Nev Brunsvick and Nova Scotia.

These data can help to interpret results from the sediment sampling program. Dioxins and furans have long half-lives (Environment Canada, 1990) once accumulated in biological tissue and represent a time integrator of these contaminants. Site-specific comparisons of fish and sediments data are beyond the objective of this report. However some examples can be used to illustrate hov both programs are complementary either to corroborate the status of contamination of a site or to indicate the need for additional sediment sampling and measures to obtain a full picture of the contamination.

- An advisory to limit consumption of some freshwater fish in Alberta was released in July 1990 by Health and Welfare Canada. Elevated levels of 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF were observed in three fish species (mountain whitefish, burbot and bull trout) obtained from Athabasca River near Hinton. High levels of these substances have also been observed in mountain whitefish from the Wapiti River near Grande Prairie. Fish from the Athabasca River were captured 15 to 20 km downstream of the Welwood Pulp mill and from 1 to 10 km downstream of Proctor and Gamble's mill on the Wapiti River. Sediment data revealed only a low level of contamination by 2,3,7,8-T_4CDF (36 pg/g) in sample 21B collected within 12 km downstream of the mill on the Wapiti River. No contamination was detected in sediment samples collected in the Athabasca River or in the Lake Athabasca.

- An advisory to limit the consumption of certain freshwater fish caught near some British Columbia inland pulp mills was issued by the federal and provincial governments in May 1989. Fish sample analyses indicated detectable levels of 2,3,7,8-T_4CDD. Sediments collected in the same areas indicated levels below the limit of quantitation (less than 15 pg/g).

- Data on fish and shellfish from the coast of British Columbia (Health and Welfare Canada, November 1989) showed elevated levels of dioxins and furans at eight of the eleven sites surveyed. In most cases, sediment data on 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF support these observations. Concentrations of 2,3,7,8-T_4CDD in sediments collected from Powell River (#10A), Gold River (#3B) and Harmac (#7B) were very low (5, 2 and 4 ppt, respectively). This potentially indicates that very low levels of contamination in sediments are a significant contamination problem. Valid data (QA/QC) are essential at such low concentrations due to the low limits of quantitation required. Baseline surveys have already been undertaken at many of these coastal areas.

- In Québec sediment data from the Lebel-sur-Quévillon area (Produits des Pâtes et Papiers Domtar) indicated contamination by 2,3,7,8-T_4CDD, 2,3,7,8-T_4CDF and P_5CDF; the 2,3,7,8-T_4CDD concentration was among the highest recorded in this survey (43 pg/g). White suckers collected from the Bell River showed low levels of dioxins and furans which are not considered to pose health problems (Government of Canada, April 1990).

- An advisory to limit brown bullhead consumption was released for the La Tuque area (St-Maurice River, Québec) due to high levels of 2,3,7,8-T_4CDD. Sediment data indicated very low concentrations of 2,3,7,8-T_4CDD (5 ppt) (Government of Canada, April 1990).

The general distribution of dioxins and furans in sediments is in sharp contrast to the congener profile found in biota, in which tetra and not hexa to octachlorinated congeners predominate (Servos, 1988). Dioxins and furans data for fish and sediments from the dioxin sampling show the same relationship. Chemical and physical properties of the contaminants can help to explain this difference. The octanol-water partition coefficient (K_{ow}) for dioxins increases as the number of chlorine atoms in the molecule increases (Shiu et al.,1988). Therefore, the higher chlorinated congeners are expected to be more rapidly bioconcentrated in aquatic biota (Servos,1988). However, it has been shown that the bioconcentration factor of CDDs and other superlipophilic compounds decrease above a log K_{ow} of approximately 6.5 (Muir et al.,1985). It has been suggested that sorption to dissolved organic matter, increased molecular size or steric hindrance and decreased solubility (Muir et al.,1985; Opperhuizen et al., 1985; Gobas and Mackay 1987) could explain the decline of bioconcentration of higher chlorinated congeners. The high affinity of CDDs for organic matter, especially the more lipophilic congeners (O_8CDD) may limit their dissolved concentrations in the water column and reduce their bioavailability in the aquatic environment (Mc Carthy et al., 1985; Servos, 1988).

A better understanding of the environmental dynamics of congeners other than 2,3,7,8-T_4CDD is important for the evaluation of the potential hazard of CDDs and CDFs in aquatic environments (Baumann et al., 1988). Although higher chlorinated dioxins and furans showed lower toxicity (based on TEQ system) and bioavailability, the high concentration and higher retentive capacity (Servos, 1988) of these congeners in aquatic sediments mean that contaminated sediments may serve as a source of CDDs to the environment and biota long after inputs have been reduced or eliminated.

The very low concentration or non detected levels of 2,3,7,8-T_4CDD in sediments in contrast to the detectable amounts in fish might be explained by a food chain transfer (biomagnification) (Servos, 1988; Muir and Yarechevski,1988). Very low concentration of 2,3,7,8-T_4CDD will likely biomagnify up the food chain and become detectable in fish although the concentration in sediments is very low. This hypothesis has important implications for the determination of the limit of detection required in the monitoring program as indicated in the previous examples. Of ten locations where 2,3,7,8-T_4CDD was detected in sediments (sites #2, #3, #7, #8, #9, #10, #14, #17, #37 and #38), eight locations were subject to an advisory on fish and/or shellfish consumption released by Health and Welfare Canada. Thus the levels required for detection in sediments are currently too close to the levels which lead to fishery closures. Data are not available for Ontario (site #26, #28, #32).

6.0 CONCLUSIONS AND RECOMMENDATIONS

Levels of dioxins and furans in bottom sediments were below the limit of detection for most of the upstream sites. Downstream of mills and in the vicinity of coastal mills, sediments were contaminated by dioxins and furans in differing degrees, varying from mill to mill. Sediments were contaminated by at least one of the dioxin or furan congeners at 95% of the mills. A large proportion (70%) of the mills showed concentrations of 2,3,7,8-T_4CDF ranging from 10 to 3179 pg/g; 2,3,7,8-T_4CDD was detected in sediments collected in the vicinity of thirteen mills (25%); at five mills sediments showed concentrations ranging from 17 to 67 pg/g while eight mills fell into the 2 to 15 pg/g range.

Contaminated samples from each site were evaluated by a contamination classification system based on Toxicity Equivalents. TEQ calculation could have led to overestimated results. At several sites, the level of contamination was high.

Sediments from British Columbia coastal mill sites were characterized by a much higher degree of contamination and a more complex mixture of dioxin and furan congeners than inland mill sediments. Coastal sediment samples are contaminated by tetra to octachlorinated dioxins and furans. In contrast, inland sediments showed a predominance of only a two congeners, octachlorinated dibenzodioxin and tetrachlorinated dibenzofuran. The pattern of dioxins and furans in coastal sediments suggest multiple contamination sources (chlorophenols, wood chips contaminated by PCP and bleaching processes).

The objective of the program was to obtain information on the presence of dioxin and furan contamination of bottom sediments in the vicinity of pulp and paper mills using chlorine bleaching. The objective was only partially achieved. The data used in this report were derived from a program that could not, due to analytical costs, permit an extensive survey at each mill. It must be clearly understood that regional offices followed the instructions of the program design regarding the number of samples to be submitted. The integration of the data in a report was difficult because the sampling approach used was not consistent. The quality of the data is, in many cases, considered unacceptable. The limited number of samples collected at each site and the absence of a QA/QC to quantify the analytical variability limit the ability of this study to assess sediment contamination with respect to dioxins and furans.

1. **It is recommended that sampling for dioxin and furan sediment contamination be increased with the objective of providing spatial variability information and establishing the representativeness of data.**

Assessment of data representativeness and comparability was hampered by the low number of samples. The database used in this report has also been compromised by other factors. Field procedure protocols were not uniform. Reduced and inadequate QA/QC activities, with insufficient ongoing evaluation and coordination, resulted in uncertainty regarding the accuracy and comparability of parts of the study results, especially for low levels (<100 pg/g) of 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF. A short review of dioxin and furan contamination in fish and shellfish (collected under this program) revealed that very low detection limit of the 2,3,7,8-T_4CDD in the sediments are required. It seems that the T_4CDD is preferentially concentrated by organisms; detection of dioxins in sediments should alert to a potential problem in biota contamination.

2. **It is recommended that a rigorous QA/QC program be implemented for sampling and analytical work with the objective of providing credible and comparable analytical data.**

Site selection is a major determinant for obtaining sediment samples shoving adequate characteristics (particle size and organic carbon content) for detecting dioxin and furan contamination. Obviously, receiving water characteristics and sedimentation processes can be very complex. Under such a high variability of conditions, a precise sampling strategy for bottom sediments requires careful planning supported by a study of specific characteristics (geology, sedimentology) for each system.

In this study, the concentration of contaminants did not shov any relationship with the proportion of fine particle or organic carbon content. We concluded that geographical factors (site locations, hydraulic and ambient conditions) and differences in contaminant sources rather than sediment characteristics were more significant considerations in the explanation of the variation observed in dioxin and furan concentrations. However, based on assumptions and scientific literature, interpretation indicated a low confidence in the contamination levels reported at over 16 sites (listed in section 4.2). Those areas not shoving contamination could be contaminated but sampling may not have been comprehensive enough to detect it.

3. It is recommended that prior to any further sediment study, in-depth evaluations of current site specific knowledge on sedimentology processes be carried out so that meaningful site selection and sampling strategy be developed. This could be achieved by specialized assessments and include a thorough survey of physical (particle size distribution) and chemical (organic carbon content) characteristics of the bottom sediments to locate depositional zones. Sampling of suspended sediments should be considered to obtain a more accurate picture of the status of contamination.

Interpretation of the relationships between sediment particle size and contamination levels indicate that a certain number of locations require additional sampling to confirm the absence of dioxin and furan contamination. An attempt has been made to formulate a list of locations to resample in priority. Also, information on effluent contamination (CPPA, 1989) and fish and shellfish contamination (Health and Welfare Canada, 1989 and 1990) was partly reviewed to confirm the status of contamination observed in the sediment survey and highlight coherent or incoherent information in the three parts of the program.

4. It is recommended that a committee be formed to concurrently review and compare data obtained from the three parts (fish, sediments, effluents) of the program and to identify, prioritize and recommend further sampling activities under the national dioxin sampling program. Scientific researchers already involved in the in-depth study carried out on the St-Maurice River should take part on this committee and provide help and support to interpret data as well as to develop recommendations (e.g. biomonitoring activities).

In summary, the sediment survey generated data that provided useful information on the presence of dioxins and furans in bottom sediments but very limited information on the representativeness and the spatial variability of the actual data. A sampling design with a different sample allocation, a better coverage based on more meaningful site locations planned on a better knowledge of sedimentology and contaminant characteristics, will help to determine more definitively the impact of pulp and paper mill discharges on the contamination of bottom sediments by dioxins and furans.

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APPENDIX A
SAMPLING SITES

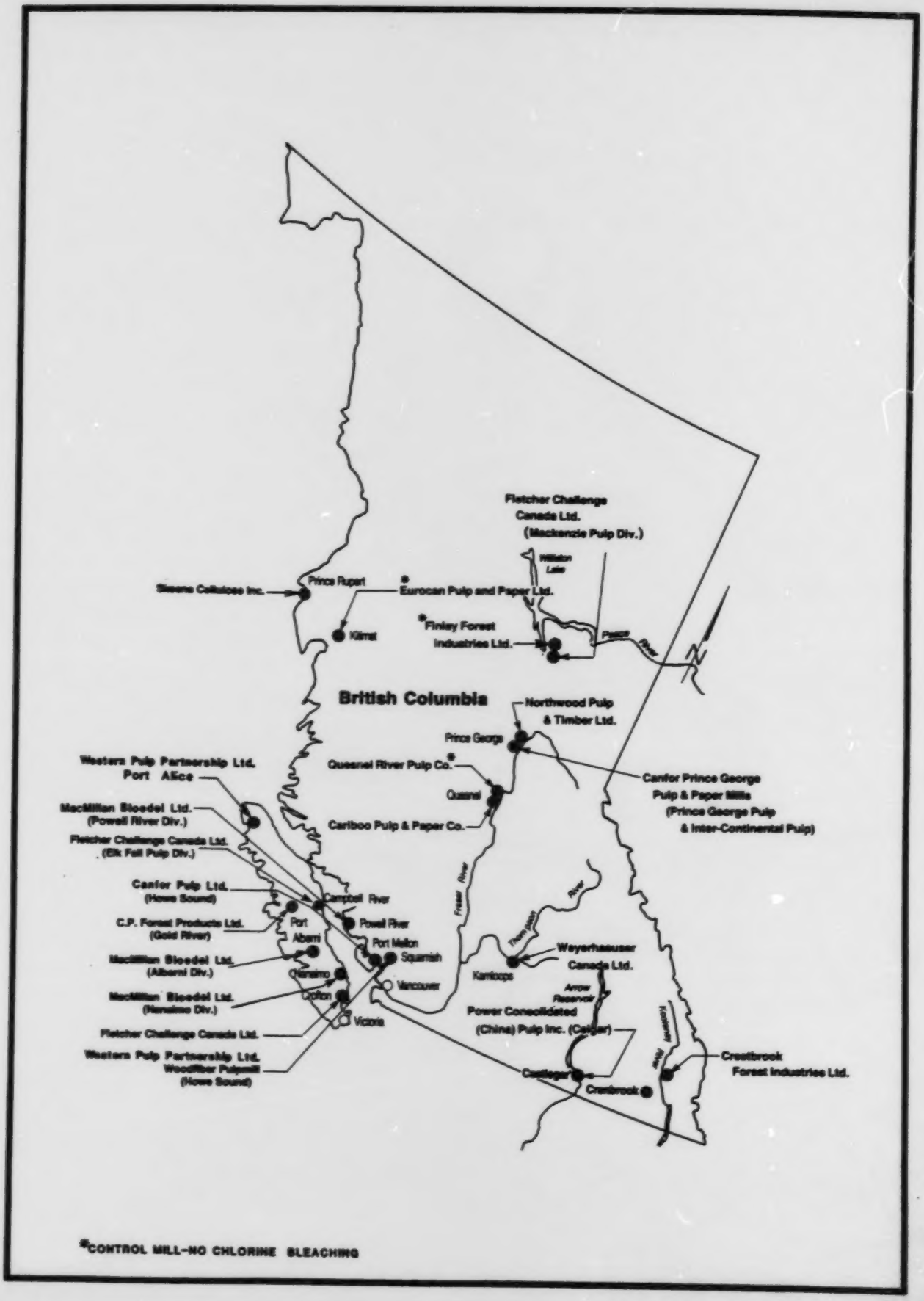
APPENDIX A-1. Location of Pulp and Paper Mills Using Chlorine Bleaching in the Regions - British Columbia, Prairies, Ontario, Québec and Atlantic.

APPENDIX A-2. Description of Sediment Sampling Sites.

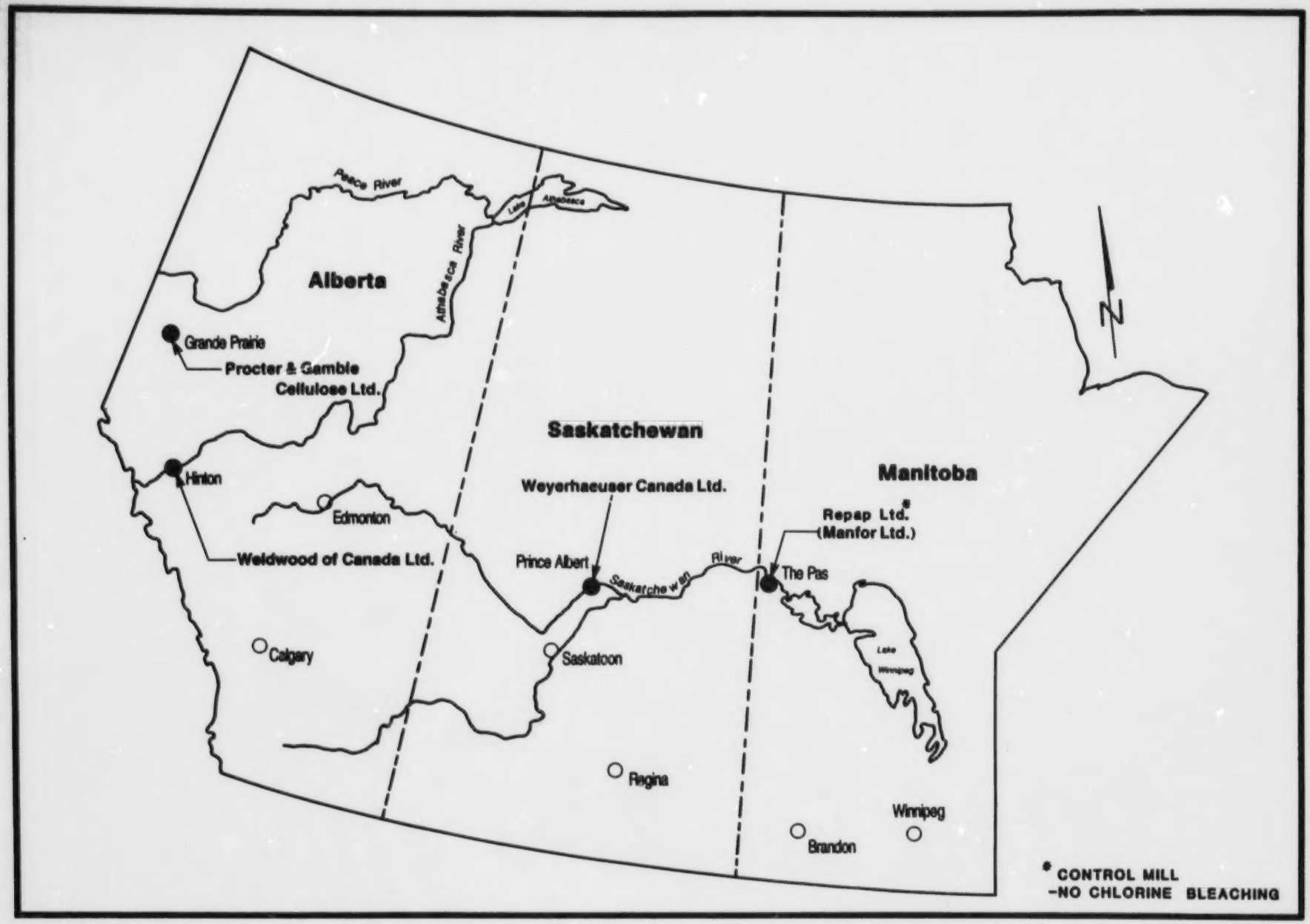
APPENDIX A-3. Location of Sediment Sampling Sites at Each Mill.

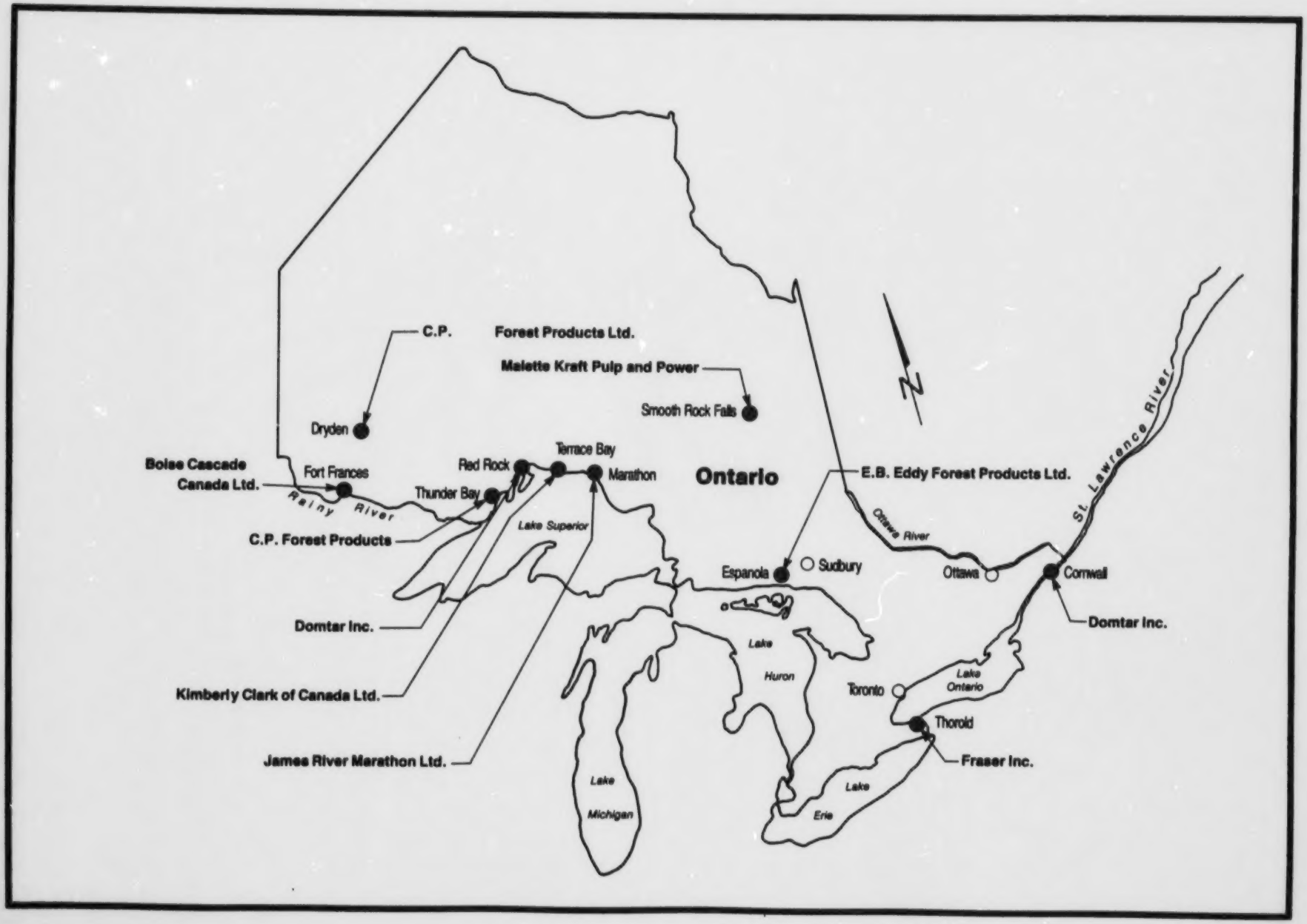
APPENDIX A-1

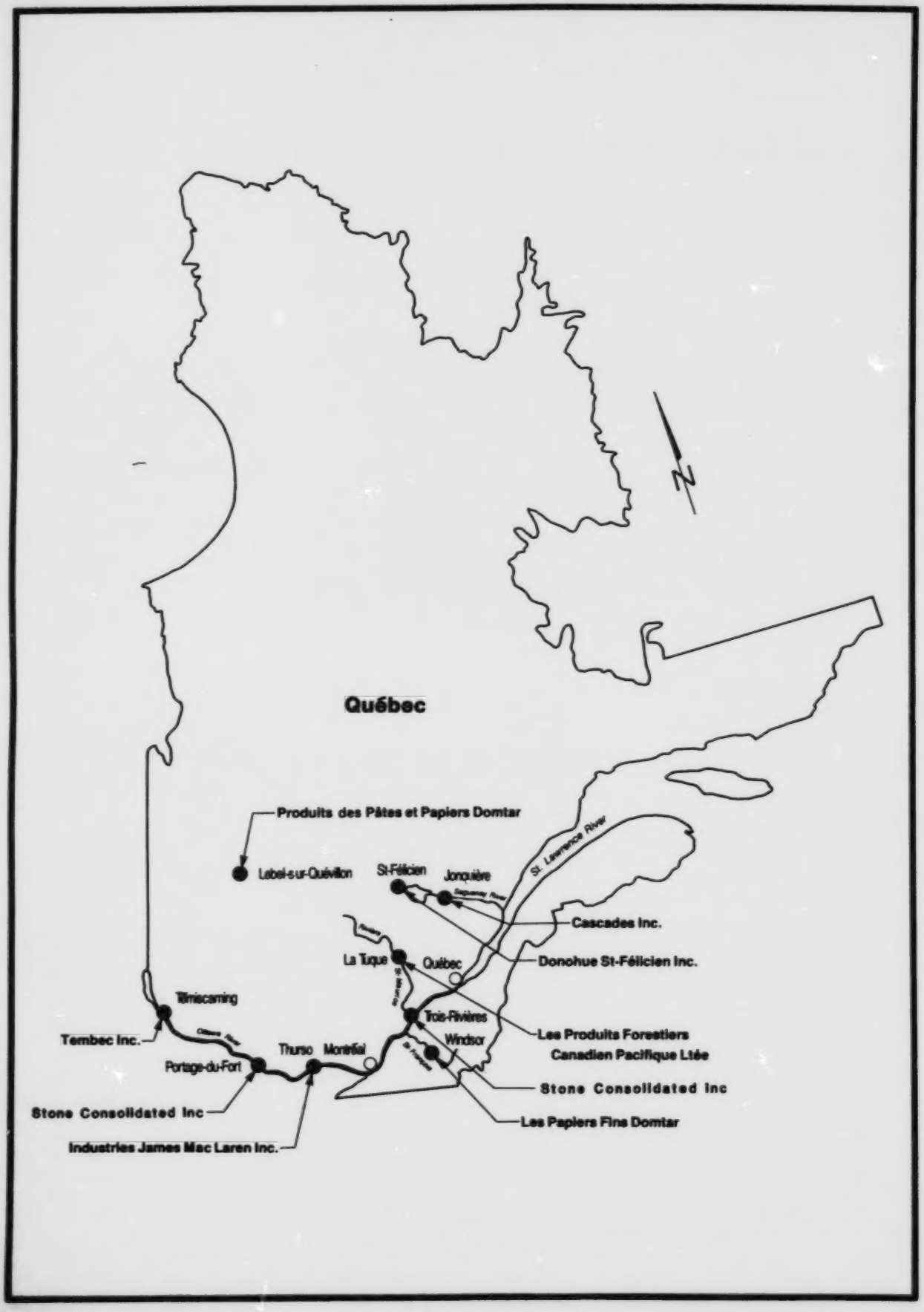
LOCATION OF PULP AND PAPER MILLS USING CHLORINE BLEACHING IN THE REGIONS - BRITISH COLUMBIA, PRAIRIES, ONTARIO, QUEBEC AND ATLANTIC

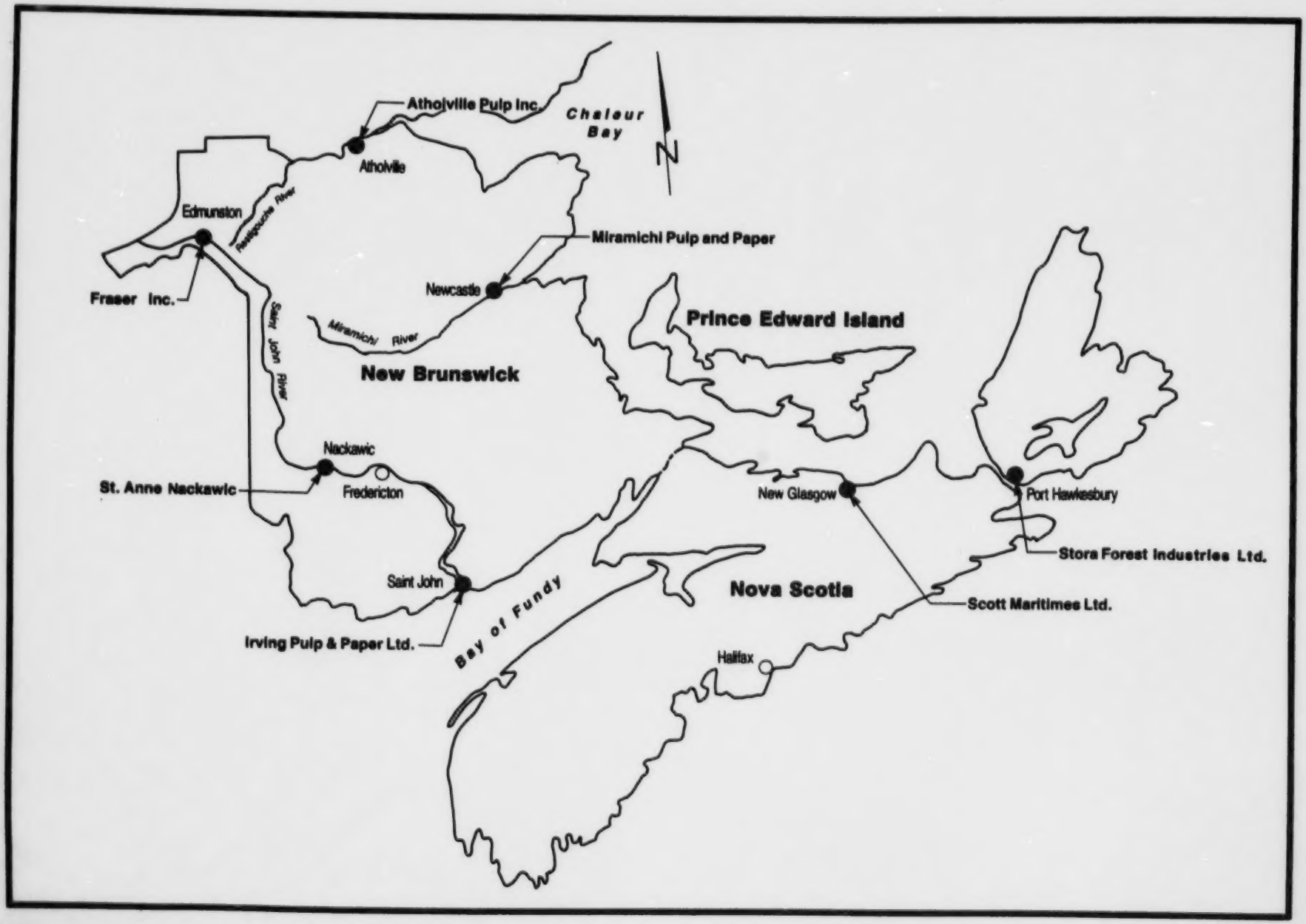


*CONTROL MILL–NO CHLORINE BLEACHING


Peace River
Lake Athabasca
Athabasca River
Alberta
Grande Prairie
Procter & Gamble
Cellulose Ltd.
Hinton
Edmonton
Weldwood of Canada Ltd.
Calgary
Saskatchewan
Weyerhaeuser Canada Ltd.
Prince Albert
Saskatchewan River
Saskatoon
Regina
Manitoba
Repap Ltd.*
(Manfor Ltd.)
The Pas
Lake Winnipeg
Winnipeg
Brandon
N
* CONTROL MILL
-NO CHLORINE BLEACHING


C.P. Forest Products Ltd.
Malette Kraft Pulp and Power
Smooth Rock Falls
Dryden
Terrace Bay
Boise Cascade Canada Ltd.
Fort Frances
Red Rock
Marathon
Ontario
E.B. Eddy Forest Products Ltd.
Thunder Bay
Rainy River
Lake Superior
Ottawa River
St. Lawrence River
C.P. Forest Products
Espanola
Sudbury
Ottawa
Cornwall
Domtar Inc.
Domtar Inc.
Lake Huron
Lake Ontario
Toronto
Kimberly Clark of Canada Ltd.
Thorold
Fraser Inc.
James River Marathon Ltd.
Lake Michigan
Lake Erie


Québec
Produits des Pâtes et Papiers Domtar
Lebel-s-ur-Quévillon
St-Félicien
Jonquière
St. Lawrence River
Cascades Inc.
Donohue St-Félicien Inc.
La Tuque
Québec
Témiscaming
Trois-Rivières
Tembec Inc.
Ottawa River
Thurso
Montréal
Windsor
Les Produits Forestiers
Canadien Pacifique Ltée
Portage-du-Fort
Stone Consolidated Inc
Stone Consolidated Inc
Les Papiers Fins Domtar
Industries James Mac Laren Inc.


Atholville Pulp Inc.
Chaleur Bay
N
Atholville
Edmunston
Restigouche River
Miramichi Pulp and Paper
Fraser Inc.
Newcastle
Miramichi River
Prince Edward Island
New Brunswick
Saint John River
Nackawic
St. Anne Nackawic
Fredericton
New Glasgow
Port Hawkesbury
Stora Forest Industries Ltd.
Saint John
Nova Scotia
Scott Maritimes Ltd.
Irving Pulp & Paper Ltd.
Bay of Fundy
Halifax

APPENDIX A-2

DESCRIPTION OF SEDIMENT SAMPLING SITES

Appendix A-2. Description of Sediment Sampling Sites

DOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C[1]
1.	Fletcher Challenge Canada Ltd. (Elk Falls Pulp Mill Div.)	Campbell River B.C.	09 Mar. 88	Strait of Georgia (Coastal)	A. At 1.3 km from the outfall	C
					B. At Painter's Lodge	C
					C. At 1.35 km from the outfall	C
2.	Fletcher Challenge Canada Ltd. (Crofton Pulp & Paper Div.)	Crofton B.C.	21 Jul 87 22 Jul 87	Osborn Bay, Strait of Georgia (Coastal)	A. Adjacent dryland log sorting area	C
					B. Adjacent pulpmill outfall	C
					C. At south wharf	C
3.	C.P. Forest Products Ltd.	Gold River B.C.	15 Feb 89	Muchalat Inlet Jacklah Bay (Coastal)	A. Jacklah Bay at 3.0 km from the discharge B. In front of pulp mill at 0.9 km from the discharge	C
4.	Weyerhaeuser Canada Ltd.	Kamloops B.C.	22 Mar 88	Thompson River (Inland)	A. S. Thompson River, 10-30 m downstream of Chase Bridge	U
					B. S. Thompson River, 1 km west of Monte Creek	U
					C. S. Thompson River, upstream of plant freshwater intake	U
					D. Thompson River, 200 m downstream of north bank diffuser	D
					E. Thompson River, 2.3 km downstream of north bank diffuser, 100 m from last sewage lagoon of Kamloops stp, north shore	D
					F. Thompson River, 8 km downstream of north bank diffuser, across from railway tunnel, north shore	D
5.	Eurocan Pulp & Paper Ltd. CONTROL MILL NO CHLORINE BLEACHING	Kitimat B.C.	08 Sept 89	Kitimat River	A. 3.5 km downstream of Hwy 25 bridge (27 km north of Kitimat) in side channel by right bank	U
					B. Just upstream of Hwy 25 bridge, left bank	U
					C. At logging road bridge, 4 km upstream of Hwy 25 bridge left bank	U

(site 5 follow on next page)

(1) U - Upstream of effluent discharge
D - Downstream of effluent discharge
C - Coastal

Appendix A-2. Description of Sediment Sampling Sites

NOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C
5.	Eurocan Pulp & Paper Ltd.	Kitimat B.C.	09 Sept 89	Kitimat River	D. Right bank, 175 m downstream of discharge pipe	D
					E. Right bank, 750 m downstream of discharge pipe	D
					F. Right bank, 1 km downstream of discharge pipe	D
			Nov 89	Kitimat River	G. South of Kitimat River mouth over Minette Bay	C
					H. Inside Kitimat Yacht Club near Alcan smelter discharge outfall	C
					I. Inside Kitimat Yacht Club, near Alcan smelter discharge outfall	C
6.	Fletcher Challenger Canada Ltd.	Mackenzie B.C.	25 May 88	Williston Lake (Inland)	A. Tudyah Lake, 20 m from right bank, near source of Pack River	U[2]
					B. Tudyah Lake, mid-channel, near source of Pack River	U[2]
					C. Tudyah Lake, 20 m from left bank, near source of Pack River	U[2]
			18 May 88		D. 20 m from effluent discharge in Williston Lake	D
			19 May 88		E. 200 m from discharge in Williston Lake	D
					F. 600 m from discharge in Williston Lake	D
7.	MacMillan Bloedel Ltd. (Harmac Div.)	Nanaimo B.C.	23 Jul 87	Strait of Georgia (Coastal)	A. Adjacent to Wood Room No. 3	C
					B. Adjacent to Planner Mill	C
					C. Adjacent to pulp mill diffuser	C
8.	MacMillan Bloedel Ltd. (Alberni Pulp & Paper Div.)	Port Alberni B.C.	24 Jul 87	Alberni Inlet (Coastal)	A. Adjacent to pulp mill discharge	C
9.	Canfor Pulp Ltd. (Howe Sound)	Port Mellon B.C.	14 Jan 88	Howe Sound (Coastal)	A. Adjacent discharge outfall port No. 1	C
					B. Adjacent discharge outfall port No. 2, about 325 m offshore	

2 - Tudyah Lake stations are located upstream of Finlay Forest Industries

Appendix A-2. Description of Sediment Sampling Sites

DOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C
10.	MacMillan Bloedel Ltd. (Powell River Div.)	Powell River B.C.	13 Jan 88	Strait of Georgia (Coastal)	A. At the end of pulp mill discharge	C
11.	Northwood Pulp & Timber Ltd.	Prince George B.C.	01 Dec 87	Fraser River (Inland)	A. 8-9 km downstream of Northwood discharge, 3 km downstream of Canfor and Intercontinental Pulp combined discharge	D[3]
			11 Apr 88		B. 250 m downstream of discharge, right bank	D[3]
					C. 300 m downstream of discharge, right bank	D[3]
					D. 500 m downstream of discharge, right bank	D[3]
12/13	Canfor Prince George Pulp & Paper and Prince George Pulp & Intercontinental Pulp Ltd.	Prince George B.C.	20 Apr 88	Fraser River (Inland)	A. Hansard, 250 m downstream of railway bridge	U[4]
					B. Hansard, 600 m downstream of railway bridge	U[4]
					C. Hansard, 1 km downstream of railway bridge	U[4]
			01 Dec 87		D. 3 km downstream of Canfor Pulp and Inter-continental Pulp combined discharge, 8-9 km downstream of Northwood discharge	D
			06 Apr 88		E. 350 m downstream of discharge, right bank	D
			07 Apr 88		F. 1.2 km from discharge, under the railway bridge, 2nd abutment from left bank	D
					G. 1.2 km from discharge, under railway bridge, 3rd abutment from left bank	D
14.	Skeena Cellulose Inc.	Prince Rupert B.C.	13 Feb 89	Hecate Strait (Coastal)	A. 200 m north of outfall	C
					B. 200 m south of outfall	C
15.	Cariboo Pulp & Paper Company	Quesnel B.C.	01 Dec 87	Fraser River (Inland)	A. 4.5 km downstream from discharge	D
			18 Mar 88		B. 2 km downstream of Cariboo discharge, right bank	D
					C. 2.2 km downstream of discharge, right bank	D
					D. 2.6 km downstream of discharge, right bank	D

3 - Upstream stations are located at Hansard on Fraser River, see Canfor Prince George (12/13 A, B, C)
4 - Hansard stations are located upstream of Northwood Pulp & Timber (11)

Appendix A-2. Description of Sediment Sampling Sites

DOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C
16.	Crestbrook Forest Industries Ltd.	Cranbrook B.C.	14 Mar 88	Kootenay River (Inland)	A. 3 km upstream of Canal Flats, east bank	U
					B. 2.5 km upstream of mill	U
					C. Where discharge and ground water seep to surface	D
					D. 300 m downstream of previous site	D
					E. 300 m downstream of previous site	D
					F. Below the effluent pipe used only during high flow conditions	D
17.	Western Pulp Partnership Ltd. (Howe sound)	Squamish (Woodfibre) B.C.	8 Dec 87	Howe Sound (Coastal)	A. Near the effluent diffuser	C
					B. 150 m from the effluent diffuser	C
					C. On the west side of Howe Sound about 2 km from the mill and 4 km from Squamish	C
18.	Finlay Forest Industries Ltd.	Mackenzie B.C.	17 May 88	Williston Lake (Inland)	A. 0.5–3 m from discharge in Williston Lake	D[5]
					B. 20 m from discharge in Williston Lake	D[5]
	CONTROL MILL NO CHLORINE BLEACHING				C. 500 m from discharge in Williston Lake	D[5]
19.	Quesnel River Pulp Co. Ltd.	Quesnel B.C.	28 Mar 88	Fraser River (Inland)	A. 3.5 km upstream of pulp mill discharge, left bank	U
	CONTROL MILL NO CHLORINE BLEACHING				B. 2 km upstream of pulp mill discharge, left bank	U
					C. 1.3 km upstream of pulp mill discharge, left bank	U
					D. 650 m downstream of discharge, left bank	D
					E. 2 km downstream of discharge, left bank	D
					F. 2.5 km downstream of discharge, left bank	D
20.	Celgar Pulp Company (Power Consolidated)	Castelgar B.C.	17 Mar 88	Columbia River (Inland)	A. Arrow Lake, at mouth of Deer Creek	U
					B. Arrow Lake, at mouth of Shield Creek	U
					C. Arrow Lake, at mouth of Syringa Creek	U
					D. Columbia River, 300 m downstream of discharge	D
					E. Columbia River, 800 m downstream of discharge	D
					F. Columbia River, 1.3 km downstream of discharge	D

5 – Upstream stations are located on Tudyah Lake, see Fletcher Challenge, Mackenzie (6A, 6B, 6C)

Appendix A-2. Description of Sediment Sampling Sites

DOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C
21.	Proctor & Gamble Cellulose Ltd.	Grande Prairie Alberta	03 Nov 88	Wapiti River (Inland)	A. Composite of 3 locations within 12 km upstream of the effluent discharge	U
					B. Composite of 3 locations within 12 km downstream the effluent discharge	D
22.	Weldwood of Canada Ltd.	Hinton Alberta	01 Nov 88	Athabasca River (Inland)	A. Composite of 3 locations spaced within 20 km upstream of pulp mill	U
					B. Composite of 3 locations spaced within 20 km downstream of pulp mill	D
			13 Mar 89	Athabasca Lake	C. Composite of 3 locations at the Athabasca River Delta 850 km downstream ca.1300 Km downstream	D
23.	Weyerhaeuser Canada Ltd.	Prince Albert Sask.	21 Nov 88	North Saskatchewan River (Inland)	A. About 15 km east of Prince Albert, at the Cecil Ferring crossing	D
24.	Manfor Ltd. (Repap)	The Pas Manitoba	16 Sept 88	Saskatchewan River (Inland)	A. About 7 km upstream of discharge, downstream side of central CNR bridge pier	U
	CONTROL MILL				B. About 5 m downstream of effluent entry to river, outermost (current side) edge of effluent delta	D
25.	Domtar Inc. (Fine Papers Div.)	Cornwall Ontario	19 Sept 89	St. Lawrence River (Inland)	A. Composite of 3 locations about 1 km upstream of the effluent (diffuser) on the north and south shores	U
					B. Composite of 3 locations spaced between within 500-800 m downstream of the effluent (north shore)	D
					C. Composite of 3 locations about 1,000 m downstream of the effluent (north shore)	D
26.	C.P. Forest Products Ltd.	Dryden Ontario	10 Jul 86	Wabigoon River (Inland)	A. Wabigoon Lake, about 15 km upstream of the mill	U
					B. Clay Lake, about 100 km downstream of the pulp mill	D
					C. Clay Lake, about 100 km downstream of the pulp mill	D
					D. Wabigoon River, about 100 m downstream of effluent discharge	D
					E. Wabigoon River, about 1 km downstream of effluent discharge	D

Appendix A-2. Description of Sediment Sampling Sites

DOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C
27.	E.B. Eddy Forest Products Ltd. (Espanola Mill Div.)	Espanola Ontario	28 Aug 89	Spanish River (Inland)	A. Composite of three locations across the river approx. 2 km upstream from the mill at the power lines	U
					B. Composite of three locations across the river downstream of the highway bridge approx. 100 m from the effluent (diffuser)	D
					C. Composite of three locations 300 m from highway bridge and 400 m from the effluent	D
28.	Boise Cascade Canada	Fort Frances	23 Oct 85	Rainy River (Inland)	A. Rainy Lake near Brule Narrows about 4.5 miles upstream of the mills	U
					B. Rainy River near Pither's Point (Fort France) about 1 miles upstream of the mills	U
					C. Rainy River along Long Sault Rapids, about 35 miles downstream of the mills (on U.S. river side)	D
			22 Oct 85		D. Four Miles Bay - Lake of the Woods near Wheelers Point, about 40 miles downstream of the mills, at mouth of Rainy River before entering Lake of the Woods	D
					E. Four Miles Bay - Lake of the Woods, about 40 miles downstream of the mills (between D and F)	D
					F. Lake of the Woods, 1 mile north of Currys Island and Sable Island about 40 miles downstream of the mills	D
29.	James River Marathon Ltd.	Marathon Ontario	03 Jul 86	Lake Superior (Inland)	A. Adjacent to effluent diffuser	D
					B. Adjacent to effluent diffuser	D
					C. Adjacent to effluent diffuser	D
					D. About 500 m from effluent diffuser, south	D
					E. In peninsula harbour	D
					F. In peninsula harbour	D

Appendix A-2. Description of Sediment Sampling Sites

DOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C
30.	Domtar Inc. (Container Board Div.)	Red Rock Ontario	03 July 86	Lake Superior Nipigon Bay (Inland)	A. Near pulp mill effluent discharge	D
					B. About 200 m from effluent discharge	D
					C. About 400 m from effluent discharge	D
			12 Sept 89		D. Background sample taken from Manokamah Bay	U
					E. One composite sample at the point source approx. 100 m directly from the effluent discharge point	D
					F. Three composite samples approx. 300 m offshore from the discharge point	D
31.	Fraser Inc.	Thorold Ontario	22 Aug 89	Old Welland Canal Twelve Mile Creek, Welland River, (to Lake Ontario)	A. Approx. 20 m from a main sewer discharge into Old Welland Canal (open ditch)	D
32.	Kimberly Clark of Canada Ltd. (Terrace Bay Div.)	Terrace Bay Ontario	03 Jul 86	Jackfish Bay Lake Superior (Inland)	A. At the mouth of Moberly Creek in Jackfish Bay	D
					B. About 500 m south of mouth of Moberly Creek at Jackfish Bay	D
					C. About 750 m south of mouth of Moberly Creek at Jackfish Bay	D
33.	C.P. Forest Products Ltd. (Thunder Bay Div.)	Thunder Bay Ontario	11 Sept 89	Kaministiugia River	A. Background sample from approx. 500 m upstream of Highway bridge (three composite samples across the river)	U
					B. Three composite samples across the river approx. 100 m directly downstream of the effluent diffuser	D
					C. Three composite samples across the river at the Turning Basin exit approx. 500 m downstream of the effluent diffuser	D
34.	Malette Kraft Pulp and Power	Smooth Rock Falls Ontario	28 Sept 89	Mattagami River	A. Three composite samples across the river approx. 200 m upstream of the Highway Bridge	U
					B. Three composite samples near the river banks and in the centre of the river approx. 30-50 m downstream from the effluent diffuser.	D
					C. Three composite samples across the river approx. 300 m downstream from the effluent diffuser	D

Appendix A-2. Description of Sediment Sampling Sites

DOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C
35.	Tembec Inc.	Temiscaming Québec	07 Oct 88	Ottawa River (Inland)	A. 100 m from the effluent discharge	D
36.	Cascades Inc.	Jonquière Québec	04 Oct 88	Saguenay River (Inland)	A. 4.5 km from the effluent discharge	D
37.	Les Produits Forestiers Canadien Pacifique Ltée.	La Tuque Québec	20 Oct 88	Saint-Maurice River (Inland)	A. 4 km from the effluent discharge	D
38.	Produits des Pâtes et Papiers Domtar	Lebel-sur-Quévillon Québec	05 Oct 88	Quévillon River (Inland	A. 4 km from the effluent discharge	D
39.	Stone Consolidated Inc. (Division Pontiac)	Portage-du-Fort Québec	13 Oct 88	Ottawa River (Inland)	A. 100 m from the effluent discharge	D
40.	Donohue St-Félicien Inc.	St-Félicien Québec	05 Oct 88	Mistassini River (Inland)	A. 1 km from the effluent discharge	D
41.	Industries James MacLaren Inc.	Thurso Québec	19 Oct 88	Ottawa River (Inland)	A. 6 km from the effluent discharge	D
42.	Stone Consolidated Inc.	Trois-Rivières Québec	12 Oct 88	Saint-Maurice River (Inland)	A. 80 km downstream of La Tuque and 10 km upstream of Trois Rivières near St. Etienne des Grès	U
					B. One composite sample from three locations in St-Maurice river downstream of effluent	D
					C. One composite sample from three locations at the mouth of St-Maurice River	D
					D. One composite sample from three locations in St. Lawrence River	D
43.	Les Papiers Fins Domtar	Windsor Québec	21 Oct 88	Saint-François River (Inland)	A. 1.5 km from the effluent discharge	D
44.	St. Anne-Nackawic Co. Ltd. Pulp and Paper	Nackawic N.B.	26 Oct 88	Saint John River (Inland)	A. 3 km upstream of outfall	U
					B. Same location as A	U
					C. 100 m downstream of outfall	D
					D. Same location as C	D
45.	Miramichi Pulp & Paper	Newcastle N.B.	18 Oct 88	Miramichi River (Estuary)[6]	A. 1.5 km upstream of outfall	U
					B. 500 m downstream of outfall	D
					C. Same location as B	D

6 - River is tidal section at point of discharge

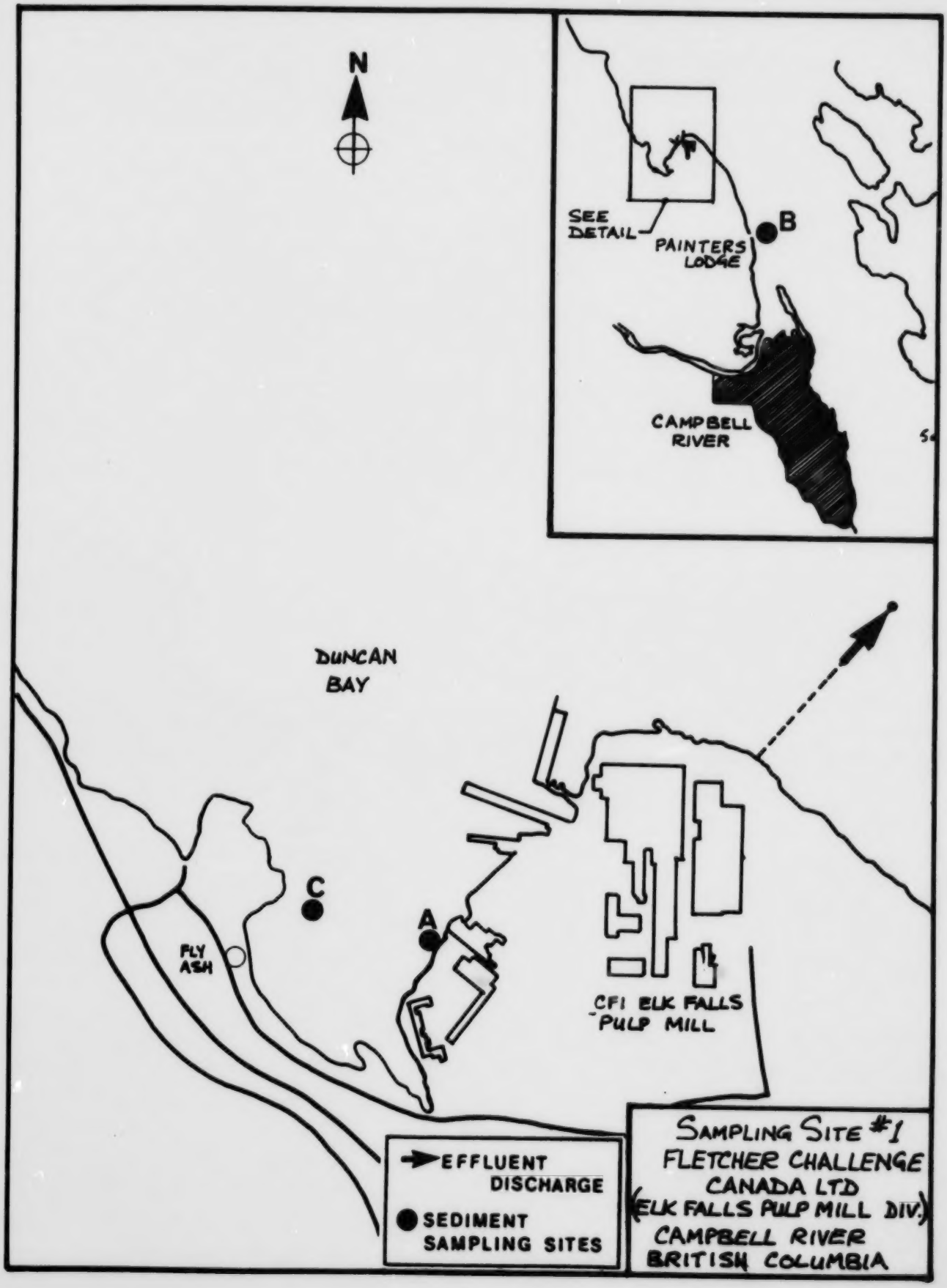
Appendix A-2. Description of Sediment Sampling Sites

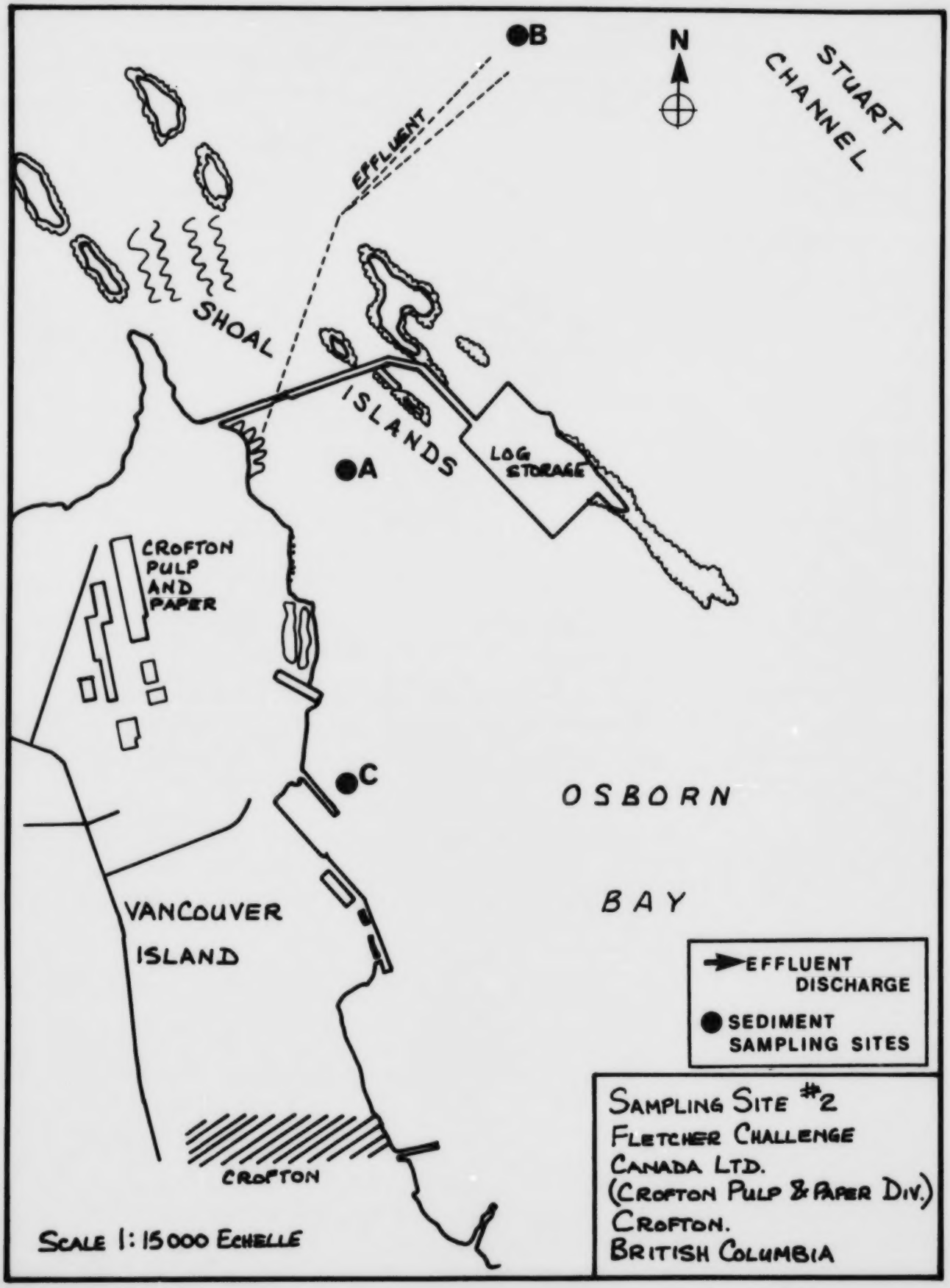
DOE No.	Firm	City, Province	Sampling Date	General Location (Coastal, Estuary, Inland)	Specific Site No. & Description	U/D/C
46.	Irving Pulp & Paper Ltd.	Saint John N.B.	01 Nov 88	Saint John River (Estuary)[6]	A. 1 km upstream from outfall	U
					B. 500 m downstream from outfall	D
47.	Atholville Pulp Inc.	Atholville N.B.	24 Oct 88	Restigouche River (Estuary)[6]	A. 3 km upstream of outfall	U
					B. 800 m downstream of outfall	D
48.	Fraser Inc.	Edmunston N.B.	25 Oct 88	Saint John River (Inland)	A. 20 km upstream of outfall	U
					B. 150 m downstream of outfall	D
49.	Scott Maritimes Ltd.	New Glasgow (Abercombie) N.S.	10 Nov 88	Northumberland Strait (Coastal)	A. 1.5 km from outfall near Lighthouse Beach at Indian reserve	C
					B. 200 m from Boat Harbour	C
50.	Stora Forest Industries Ltd.	Port Hawkesbury N.S.	02 Nov 88	Strait of Canso (Coastal)	A. Near Old Ferry Wharf	C
					B. 50 m from outfall	C
51.	Western Pulp Partnership	Port Alice, B.C.	Dec. 88	-	A. Site No. 1 - Immediately northeast of the pulp mill diffuser	C
					B. Site No. 2 - In the same area than sample A	C

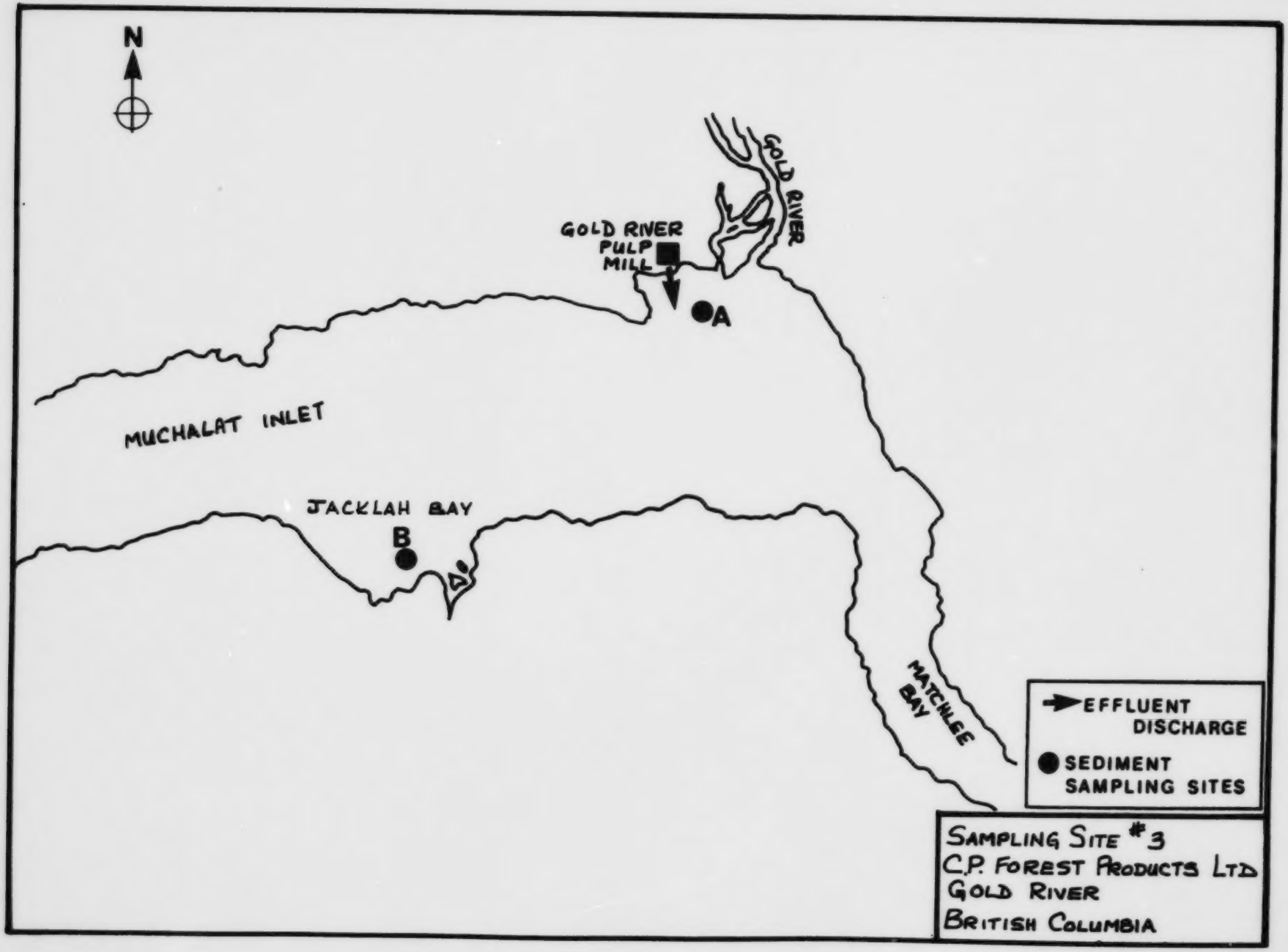
[6] - River is tidal section at point of discharge

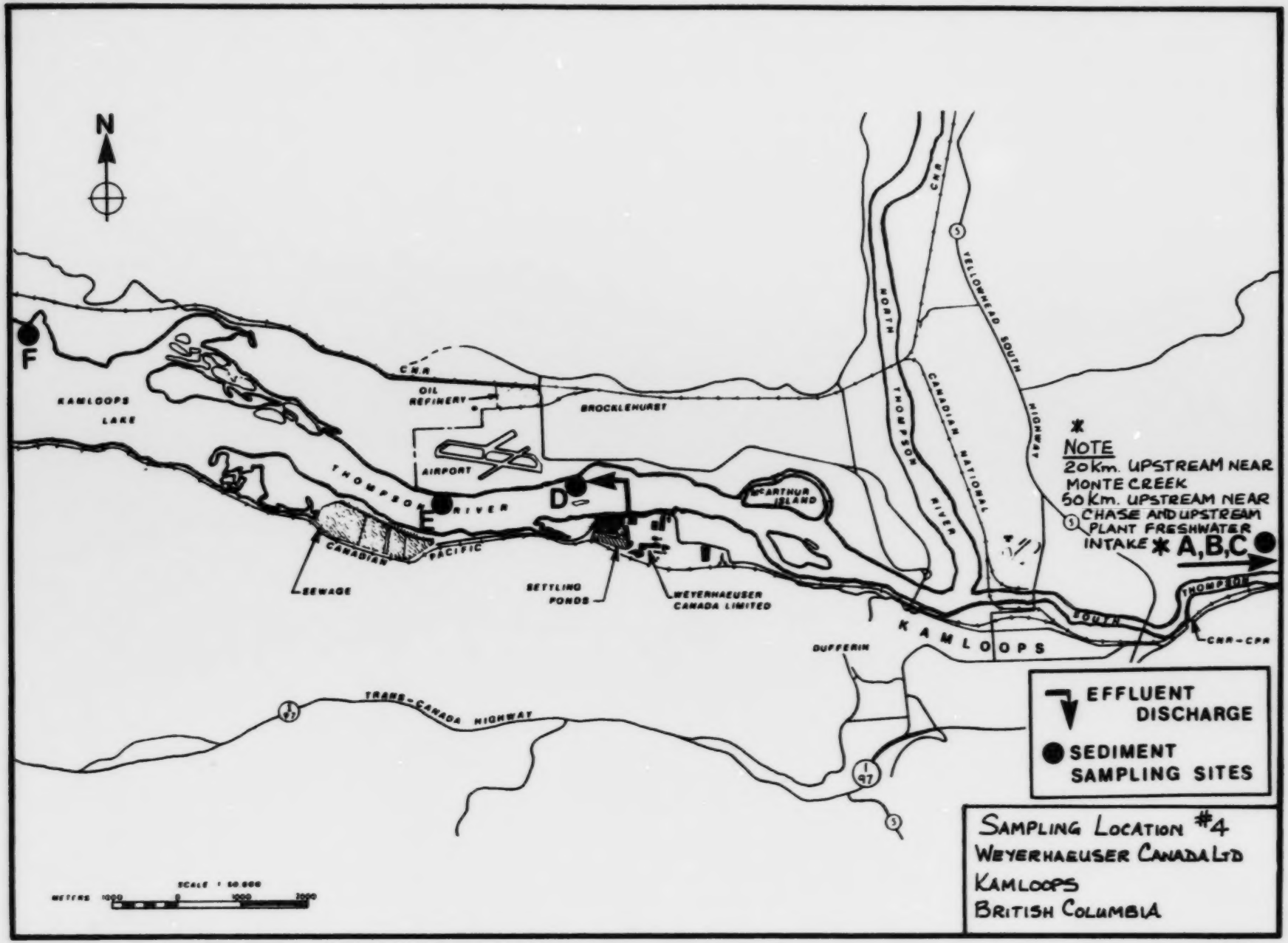
APPENDIX A-3

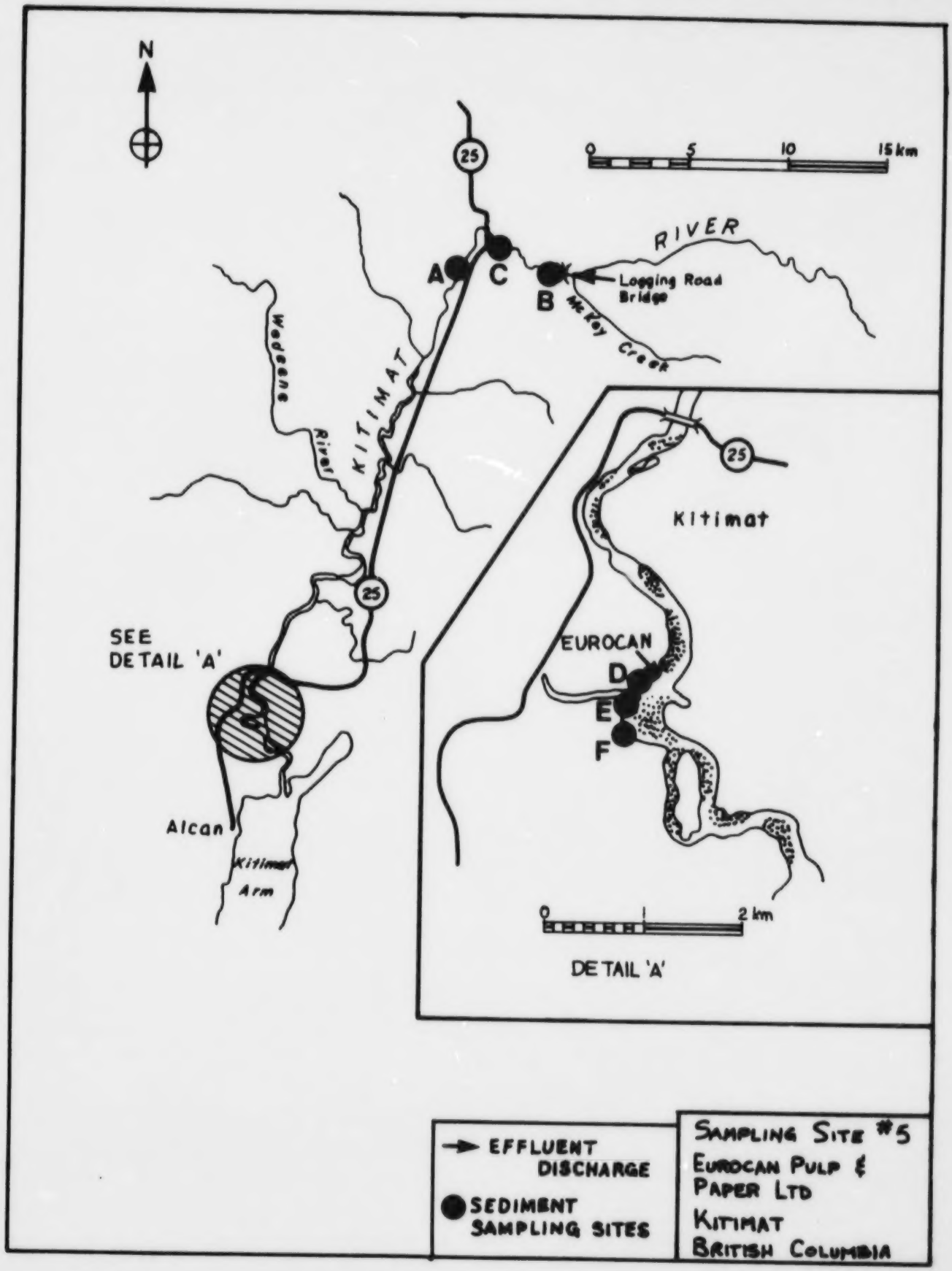
LOCATION OF SEDIMENT SAMPLING SITES AT EACH MILL

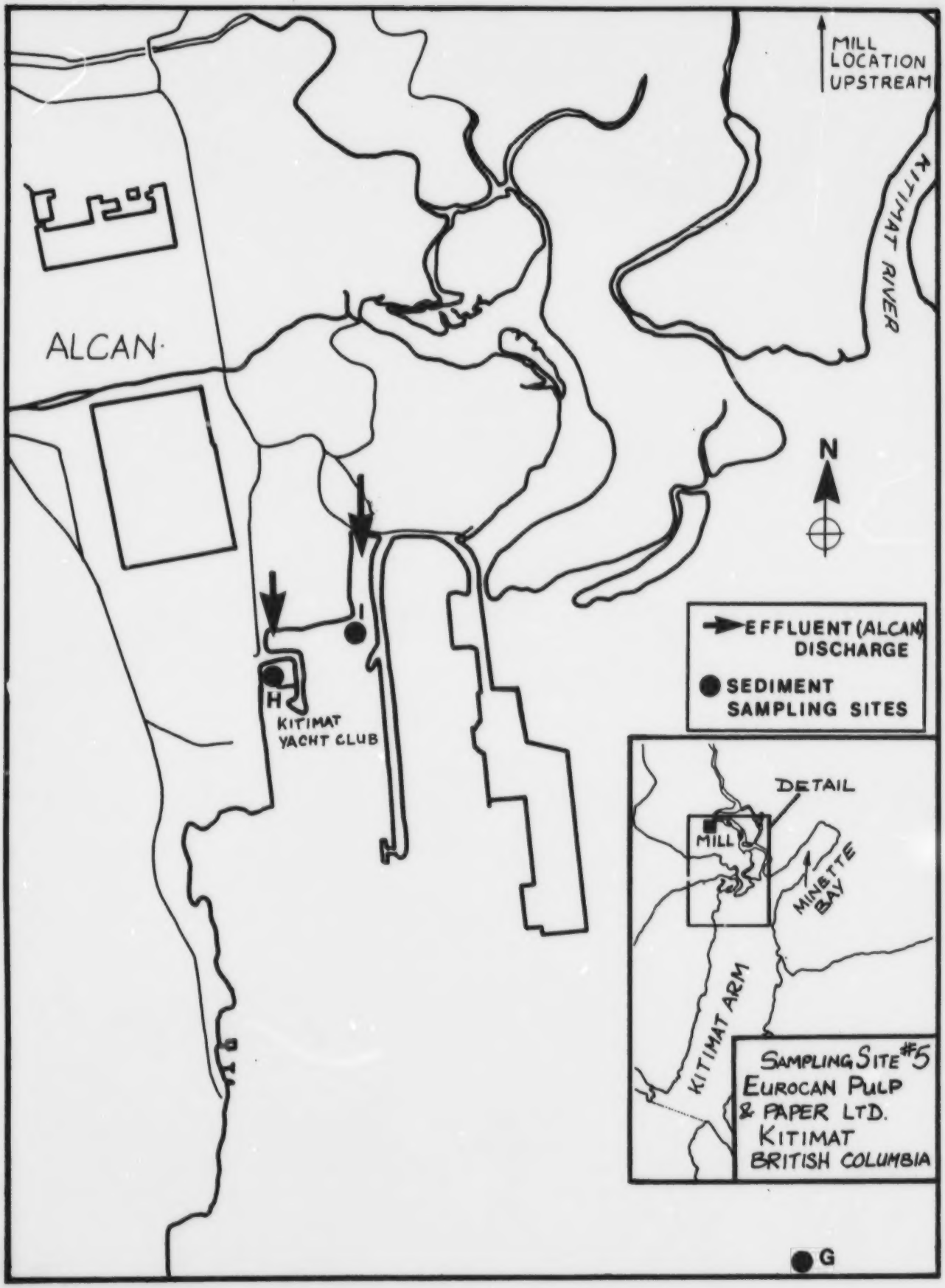

N
SEE DETAIL
PAINTERS LODGE
B
CAMPBELL RIVER
DUNCAN BAY
C
A
FLY ASH
CFI ELK FALLS PULP MILL
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #1
FLETCHER CHALLENGE CANADA LTD
(ELK FALLS PULP MILL DIV.)
CAMPBELL RIVER
BRITISH COLUMBIA

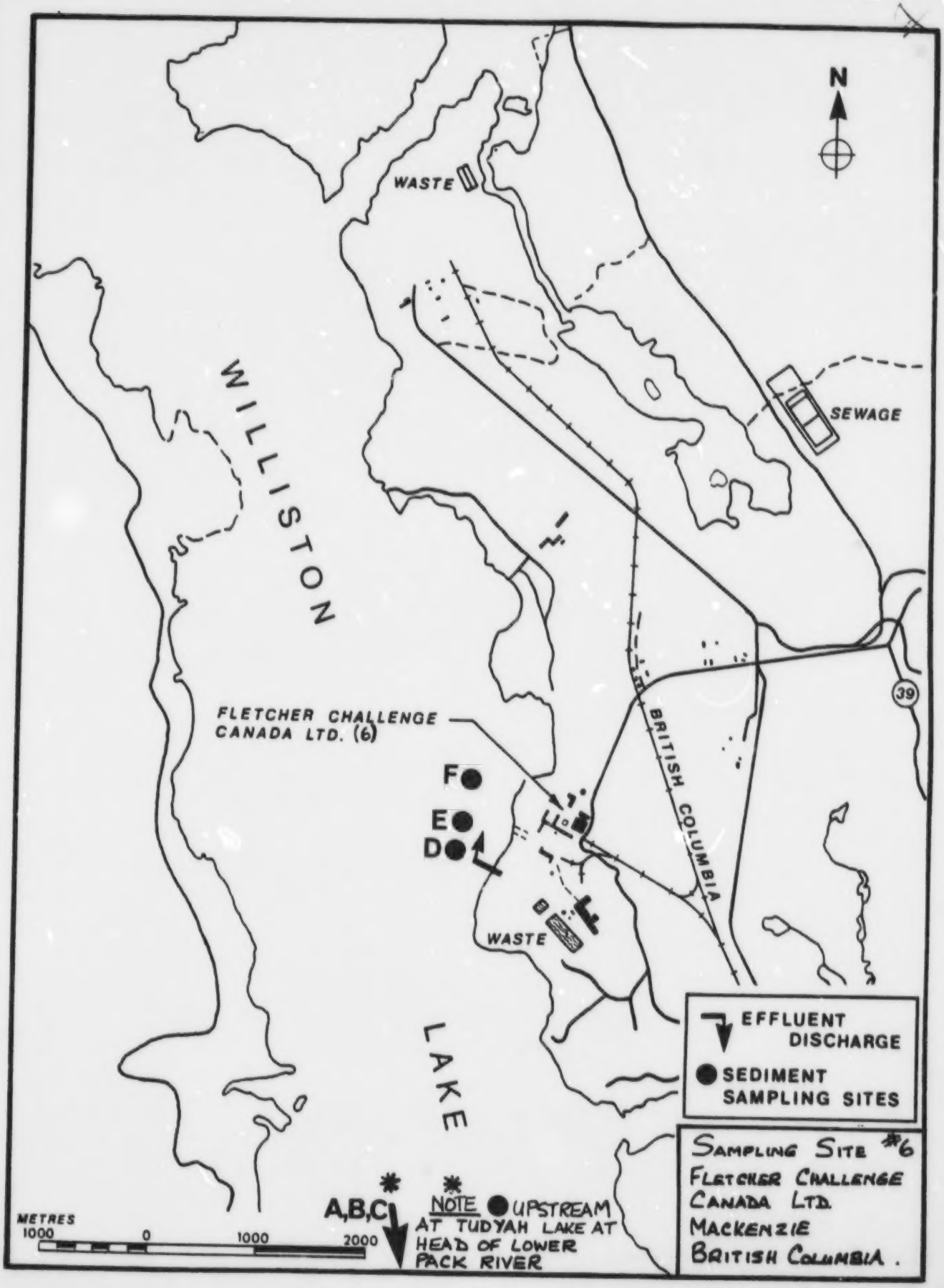

B
N
STUART CHANNEL
EFFLUENT
SHOAL
ISLANDS
A
LOG STORAGE
CROFTON PULP AND PAPER
C
OSBORN BAY
VANCOUVER ISLAND
CROFTON
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #2
FLETCHER CHALLENGE CANADA LTD.
(CROFTON PULP & PAPER DIV.)
CROFTON.
BRITISH COLUMBIA
SCALE 1:15000 ECHELLE

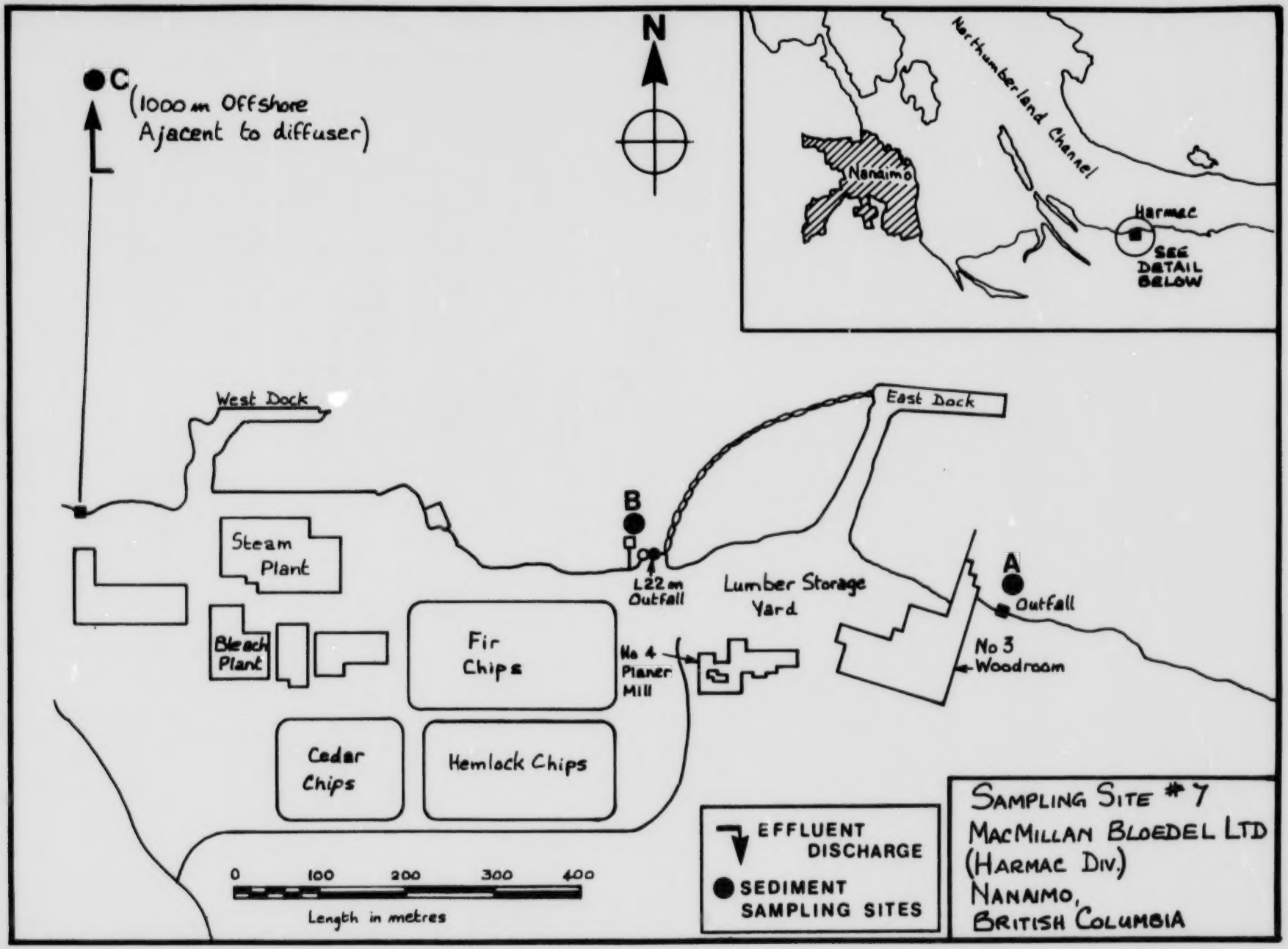

N
GOLD RIVER
GOLD RIVER PULP MILL
A
MUCHALAT INLET
JACKLAH BAY
B
MATCHLEE BAY
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #3
C.P. FOREST PRODUCTS LTD
GOLD RIVER
BRITISH COLUMBIA

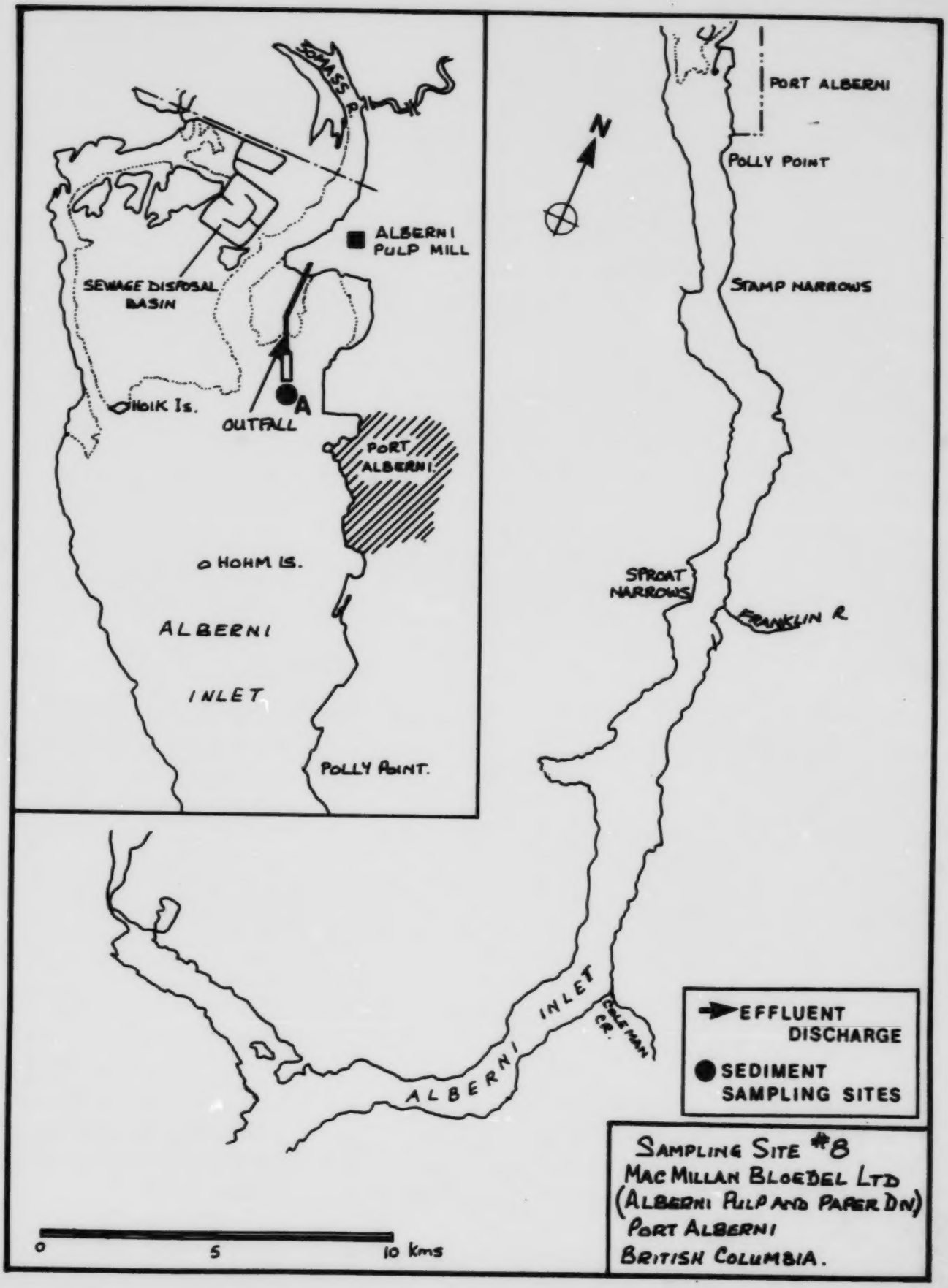

N
F
KAMLOOPS LAKE
C.N.R.
OIL REFINERY
BROCKLEHURST
AIRPORT
THOMPSON RIVER
E
D
MCARTHUR ISLAND
CANADIAN PACIFIC
SEWAGE
SETTLING PONDS
WEYERHAEUSER CANADA LIMITED
NORTH THOMPSON RIVER
CANADIAN NATIONAL
YELLOWHEAD SOUTH HIGHWAY
C.N.R.
NOTE
20 Km. UPSTREAM NEAR MONTE CREEK
50 Km. UPSTREAM NEAR CHASE AND UPSTREAM PLANT FRESHWATER INTAKE
A,B,C
THOMPSON
SOUTH
KAMLOOPS
C.N.R.-C.P.R.
DUFFERIN
TRANS-CANADA HIGHWAY
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SCALE 1:50,000
METERS 1000 0 1000 2000
SAMPLING LOCATION #4
WEYERHAEUSER CANADA LTD
KAMLOOPS
BRITISH COLUMBIA

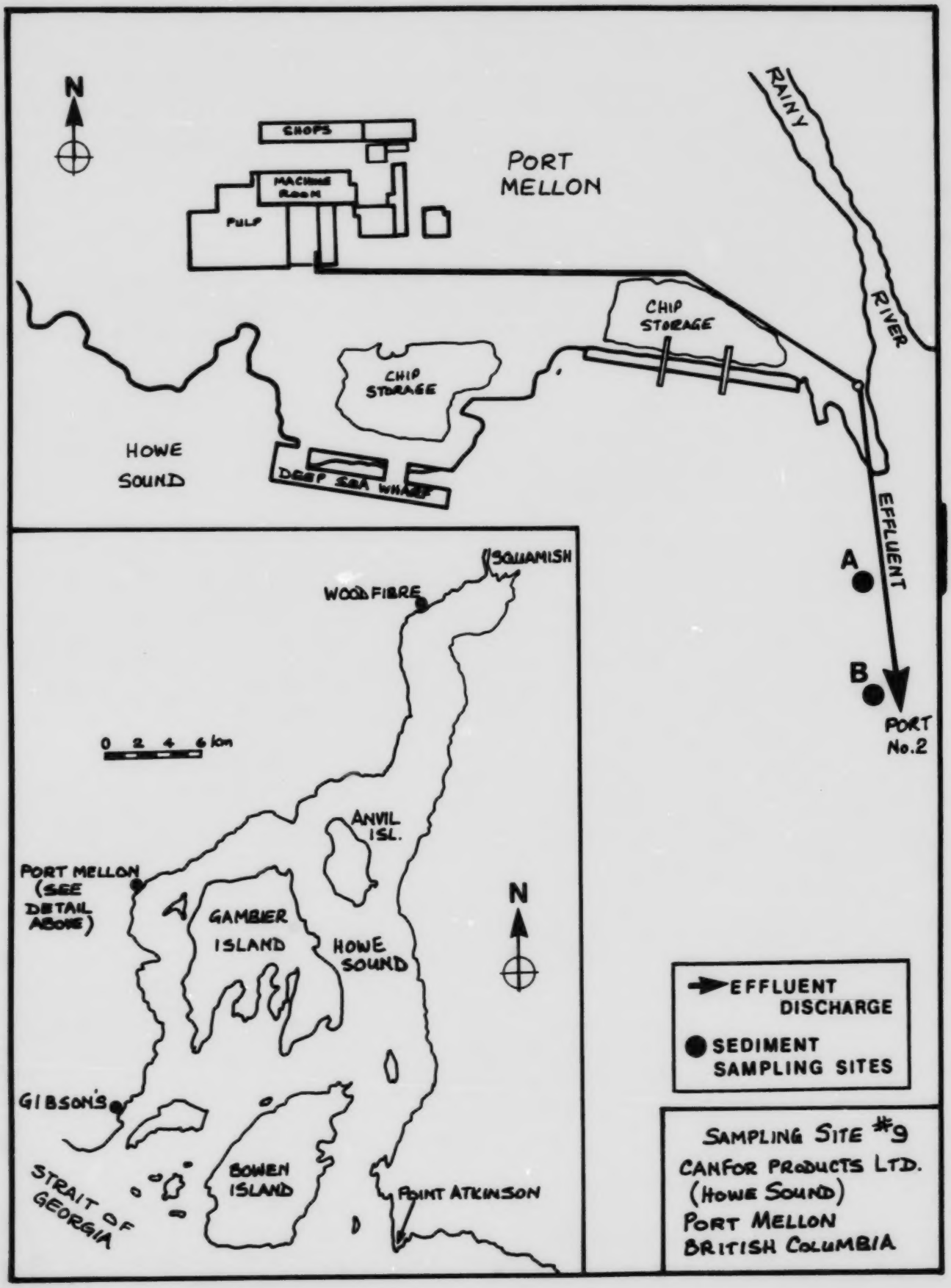

N
0 5 10 15 km
25
RIVER
A
C
B
Logging Road Bridge
McKay Creek
Wedgeene River
KITIMAT
SEE DETAIL 'A'
Alcan
Kitimat Arm
Kitimat
EUROCAN
D
E
F
0 1 2 km
DETAIL 'A'
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #5
EUROCAN PULP & PAPER LTD
KITIMAT
BRITISH COLUMBIA

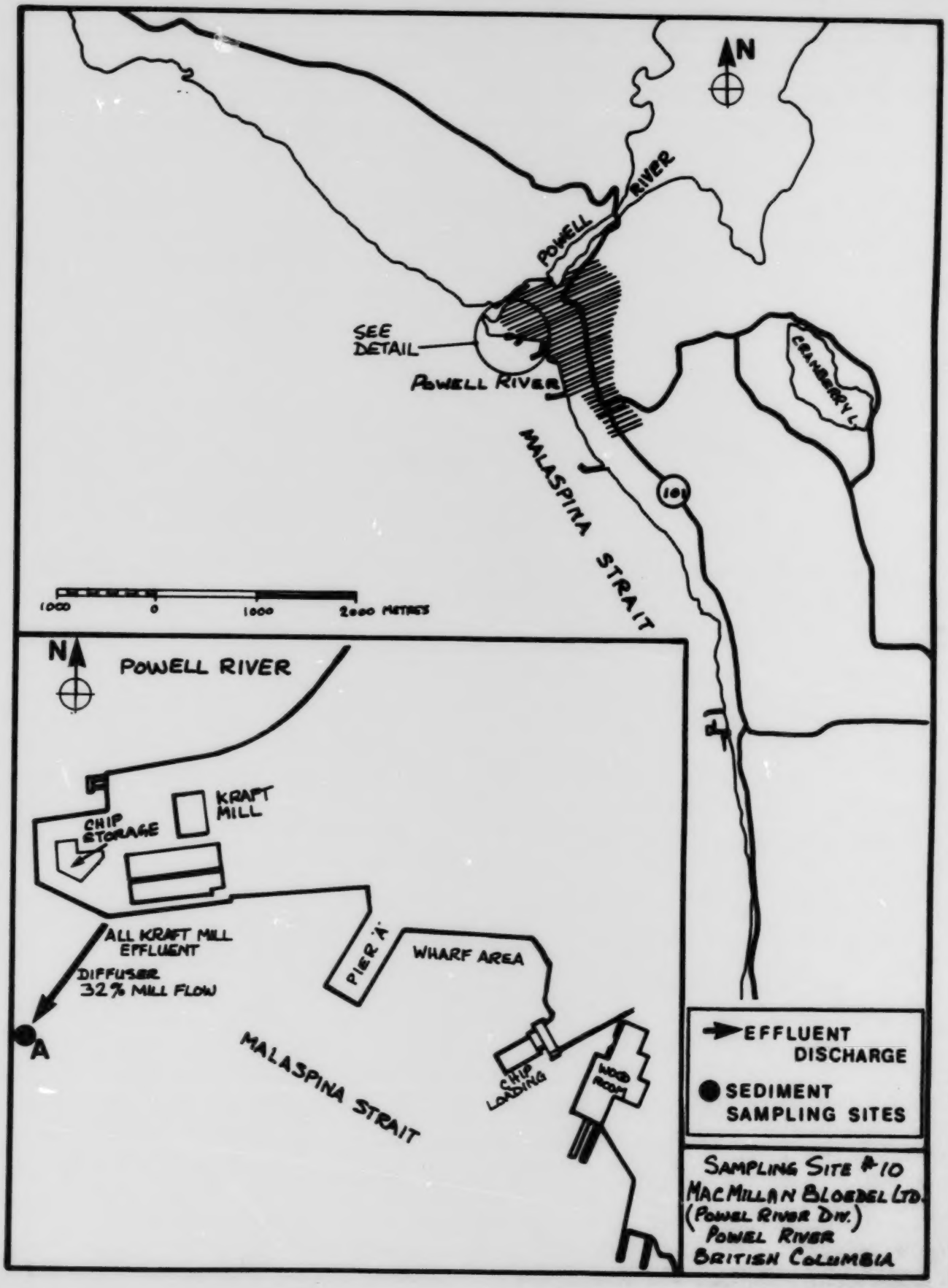

MILL
LOCATION
UPSTREAM
KITIMAT RIVER
ALCAN
N
EFFLUENT (ALCAN)
DISCHARGE
SEDIMENT
SAMPLING SITES
H
KITIMAT
YACHT CLUB
I
DETAIL
MILL
MINETTE
BAY
KITIMAT ARM
SAMPLING SITE #5
EUROCAN PULP
& PAPER LTD.
KITIMAT
BRITISH COLUMBIA
G

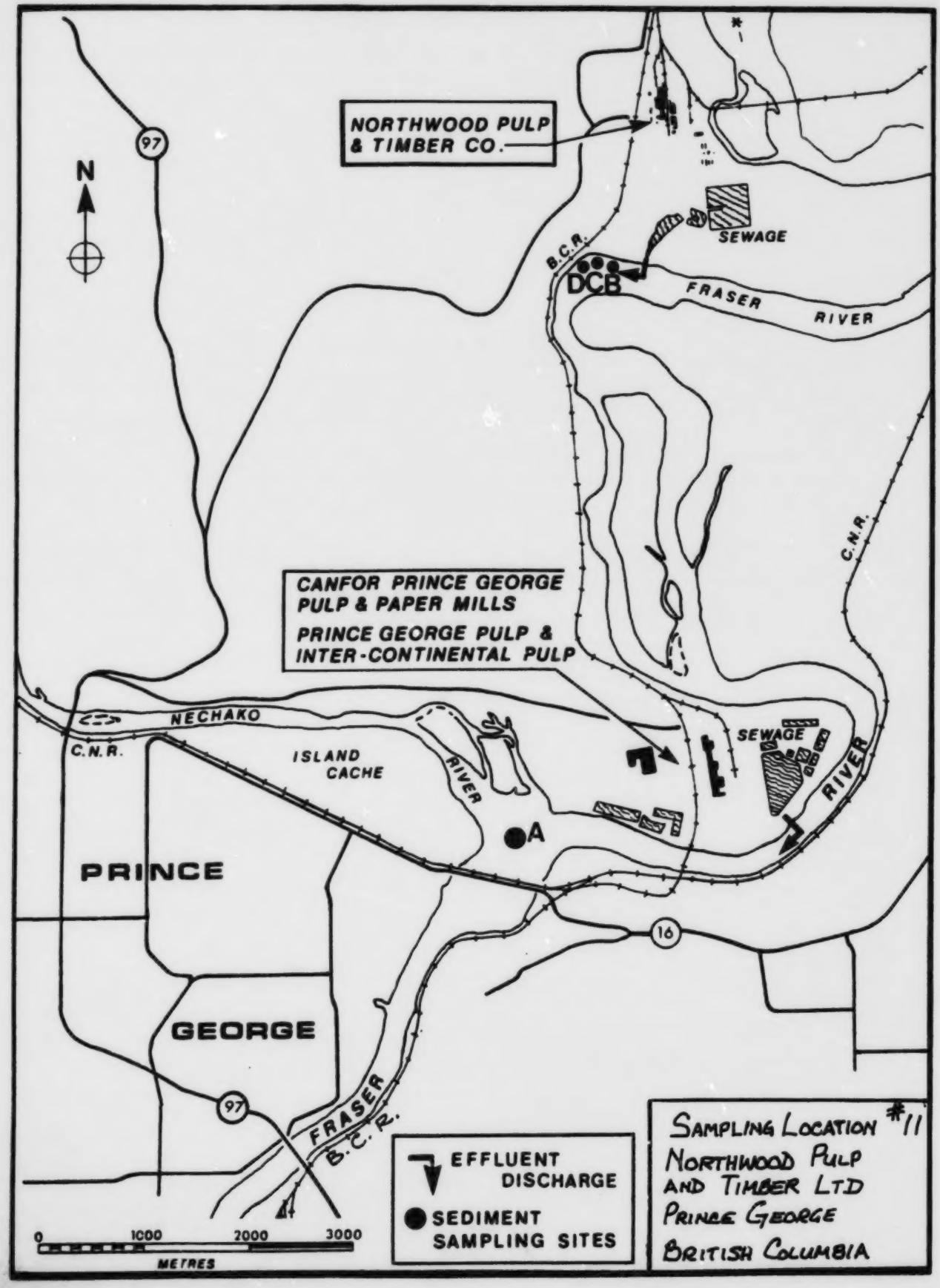

N
WASTE
WILLISTON
SEWAGE
FLETCHER CHALLENGE
CANADA LTD. (6)
F
E
D
BRITISH COLUMBIA
39
WASTE
LAKE
EFFLUENT
DISCHARGE
SEDIMENT
SAMPLING SITES
SAMPLING SITE #6
FLETCHER CHALLENGE
CANADA LTD.
MACKENZIE
BRITISH COLUMBIA.
METRES
1000
0
1000
2000
A,B,C
NOTE UPSTREAM
AT TUDYAH LAKE AT
HEAD OF LOWER
PACK RIVER

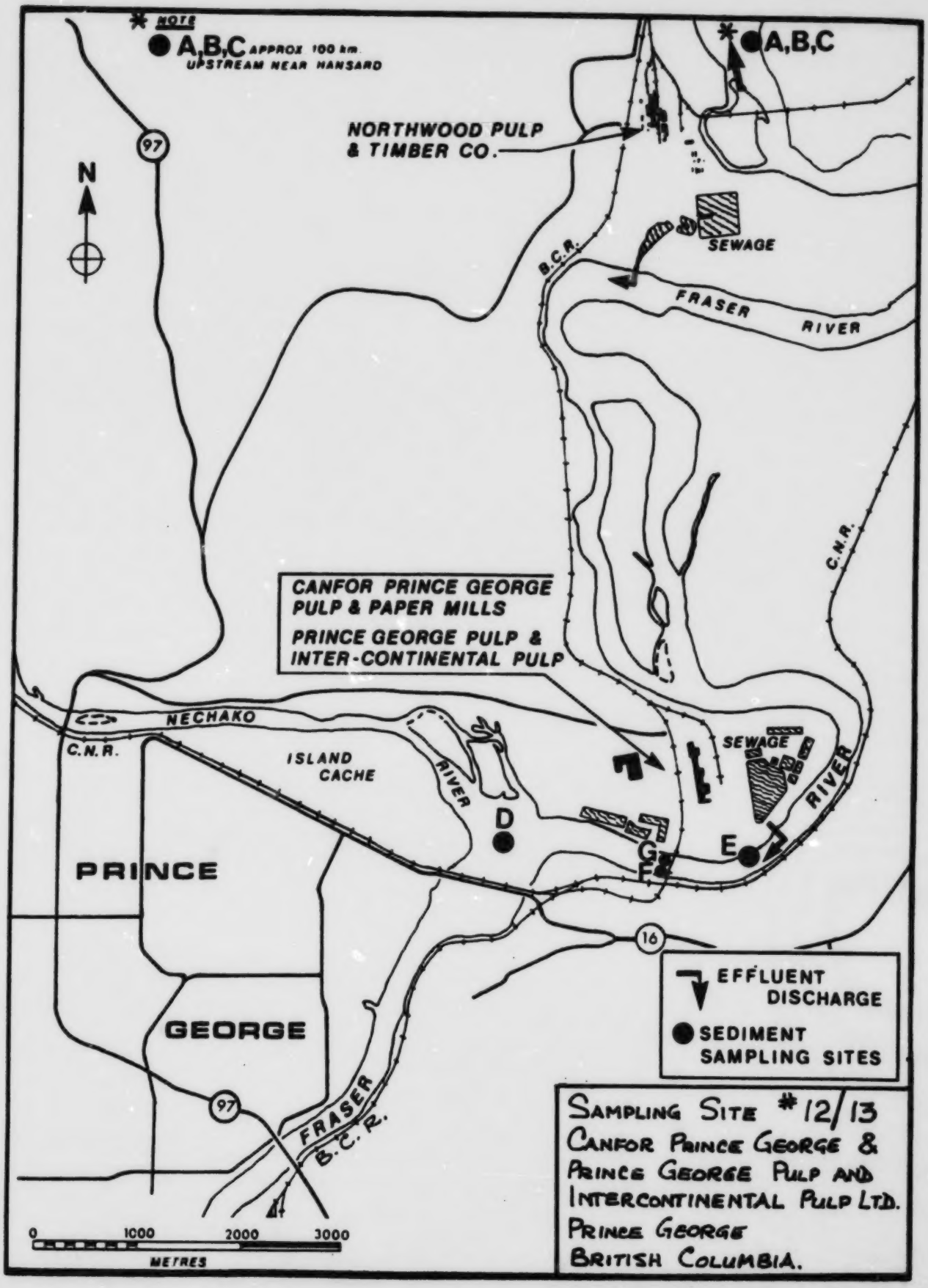

C
(1000 m Offshore
Ajacent to diffuser)
N
Northumberland Channel
Nanaimo
Harmac
SEE DETAIL BELOW
West Dock
East Dock
B
A
Steam Plant
Bleach Plant
L22 m Outfall
Lumber Storage Yard
Outfall
No 3 Woodroom
No 4 Planer Mill
Fir Chips
Cedar Chips
Hemlock Chips
0 100 200 300 400
Length in metres
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #7
MACMILLAN BLOEDEL LTD
(HARMAC DIV.)
NANAIMO,
BRITISH COLUMBIA

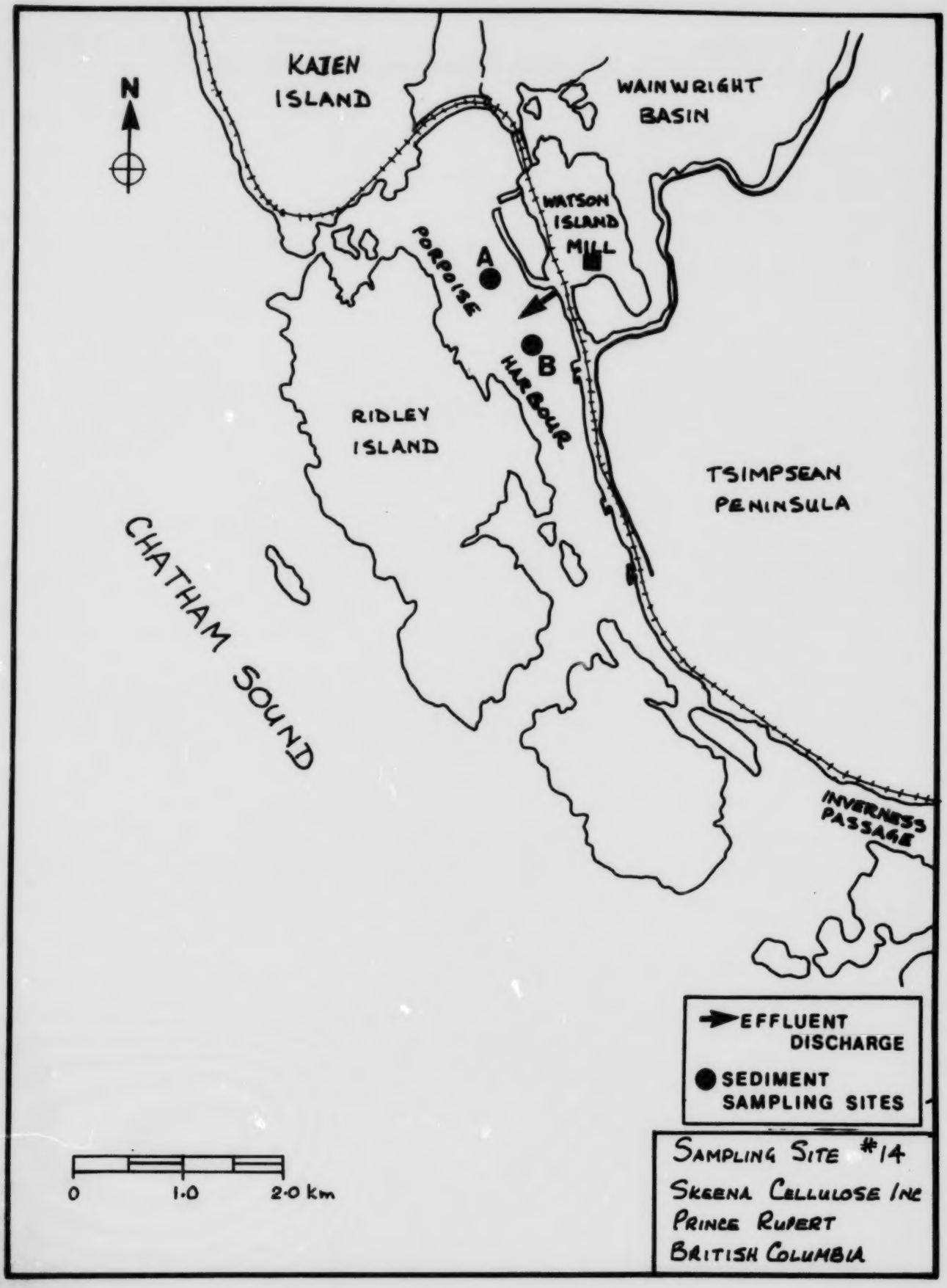

SOMASS R.
ALBERNI PULP MILL
SEWAGE DISPOSAL BASIN
HOIK Is.
OUTFALL
A
PORT ALBERNI
HOHM Is.
ALBERNI INLET
POLLY POINT
N
PORT ALBERNI
POLLY POINT
STAMP NARROWS
SPROAT NARROWS
FRANKLIN R.
ALBERNI INLET
COLEMAN CR.
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
0
5
10 kms
SAMPLING SITE #8
MACMILLAN BLOEDEL LTD
(ALBERNI PULP AND PAPER DIV)
PORT ALBERNI
BRITISH COLUMBIA.

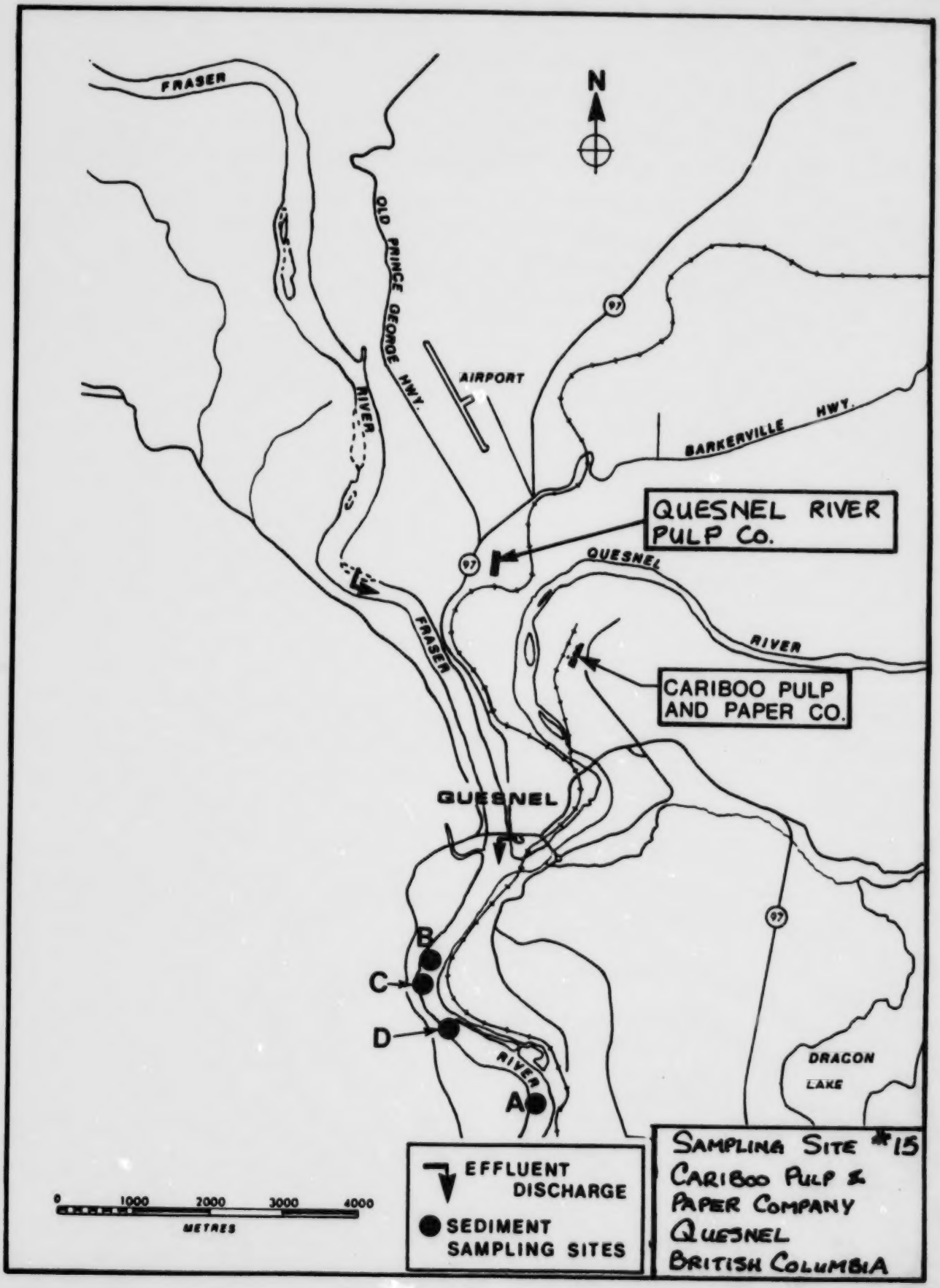

N
CHOPS
MACHINE ROOM
PULP
PORT MELLON
RAINY
RIVER
CHIP STORAGE
CHIP STORAGE
HOWE SOUND
DEEP SEA WHARF
EFFLUENT
A
B
PORT No.2
SQUAMISH
WOOD FIBRE
0 2 4 6 km
ANVIL ISL.
PORT MELLON (SEE DETAIL ABOVE)
GAMBIER ISLAND
HOWE SOUND
N
GIBSON'S
STRAIT OF GEORGIA
BOWEN ISLAND
POINT ATKINSON
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #9
CANFOR PRODUCTS LTD.
(HOWE SOUND)
PORT MELLON
BRITISH COLUMBIA

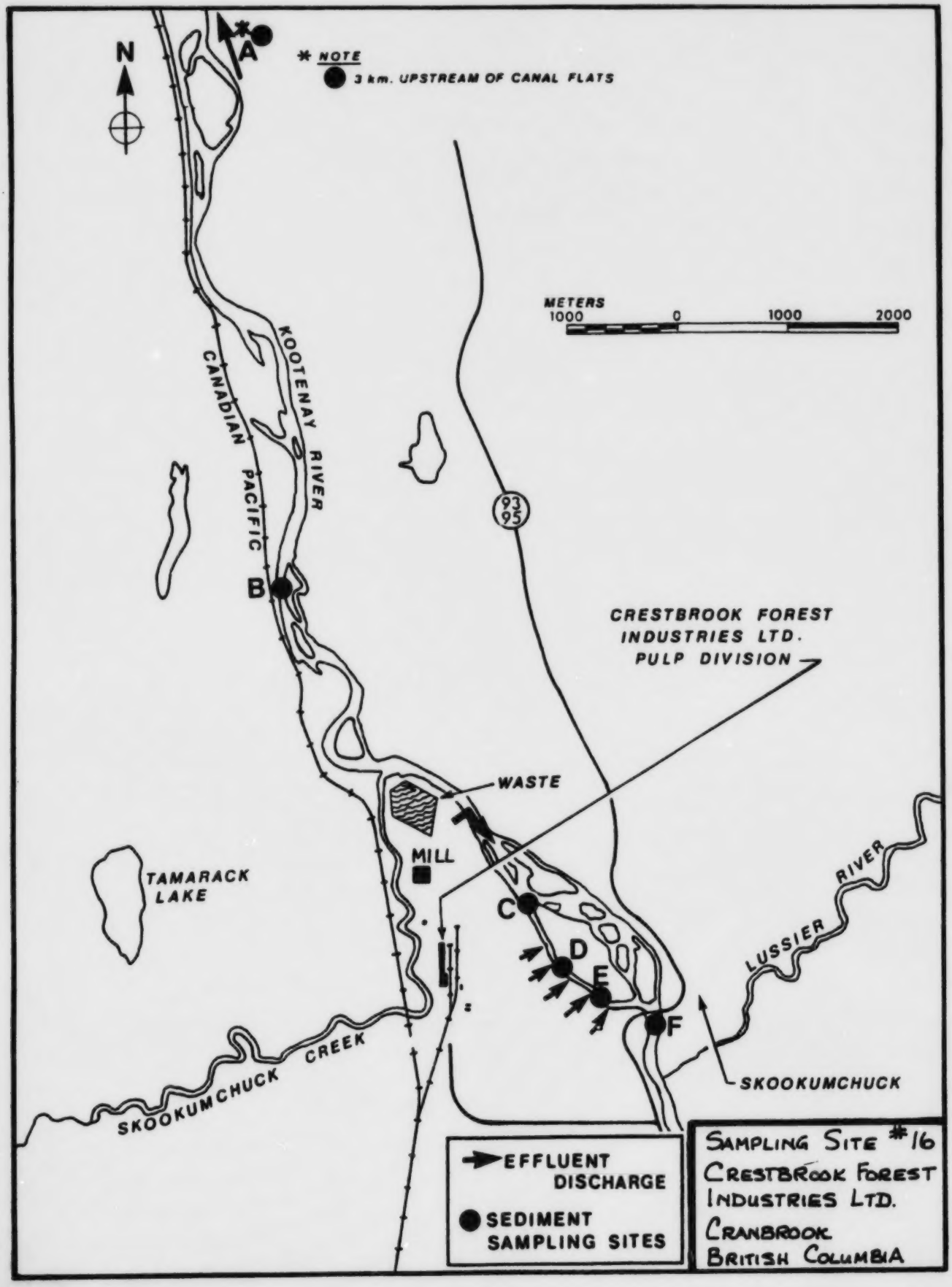

N
POWELL RIVER
SEE DETAIL
POWELL RIVER
MALASPINA STRAIT
CRANBERRY L.
101
1000 0 1000 2000 METRES
N
POWELL RIVER
KRAFT MILL
CHIP STORAGE
ALL KRAFT MILL EFFLUENT
DIFFUSER
32% MILL FLOW
A
PIER 'A'
WHARF AREA
CHIP LOADING
WOOD ROOM
MALASPINA STRAIT
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #10
MACMILLAN BLOEDEL LTD.
(POWEL RIVER DIV.)
POWEL RIVER
BRITISH COLUMBIA

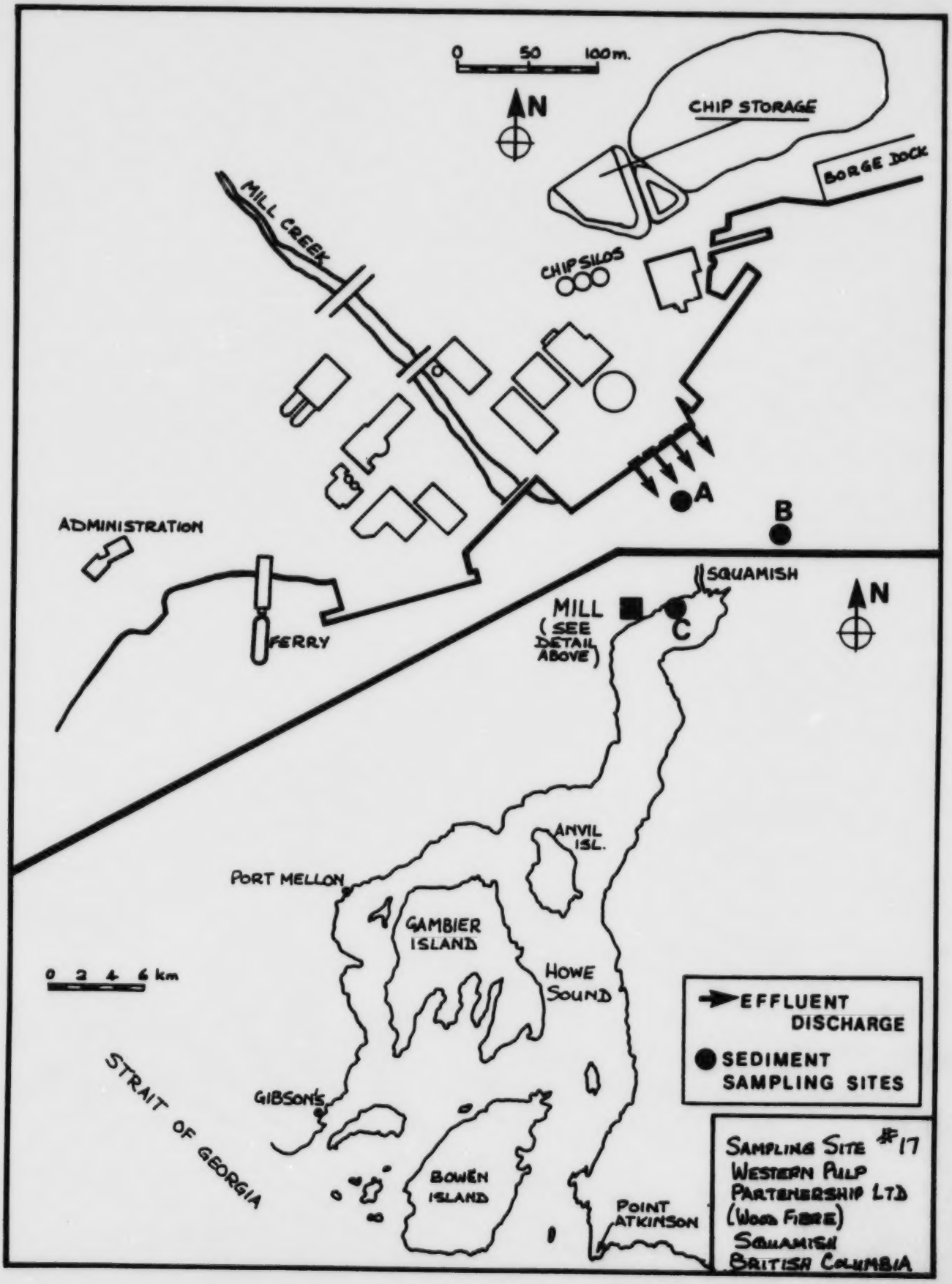

NORTHWOOD PULP & TIMBER CO.
N
97
SEWAGE
B.C.R.
DCB
FRASER RIVER
C.N.R.
CANFOR PRINCE GEORGE PULP & PAPER MILLS
PRINCE GEORGE PULP & INTER-CONTINENTAL PULP
NECHAKO
C.N.R.
ISLAND CACHE
RIVER
SEWAGE
RIVER
A
PRINCE
16
GEORGE
97
FRASER
B.C.R.
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
0 1000 2000 3000
METRES
SAMPLING LOCATION #11
NORTHWOOD PULP AND TIMBER LTD
PRINCE GEORGE
BRITISH COLUMBIA

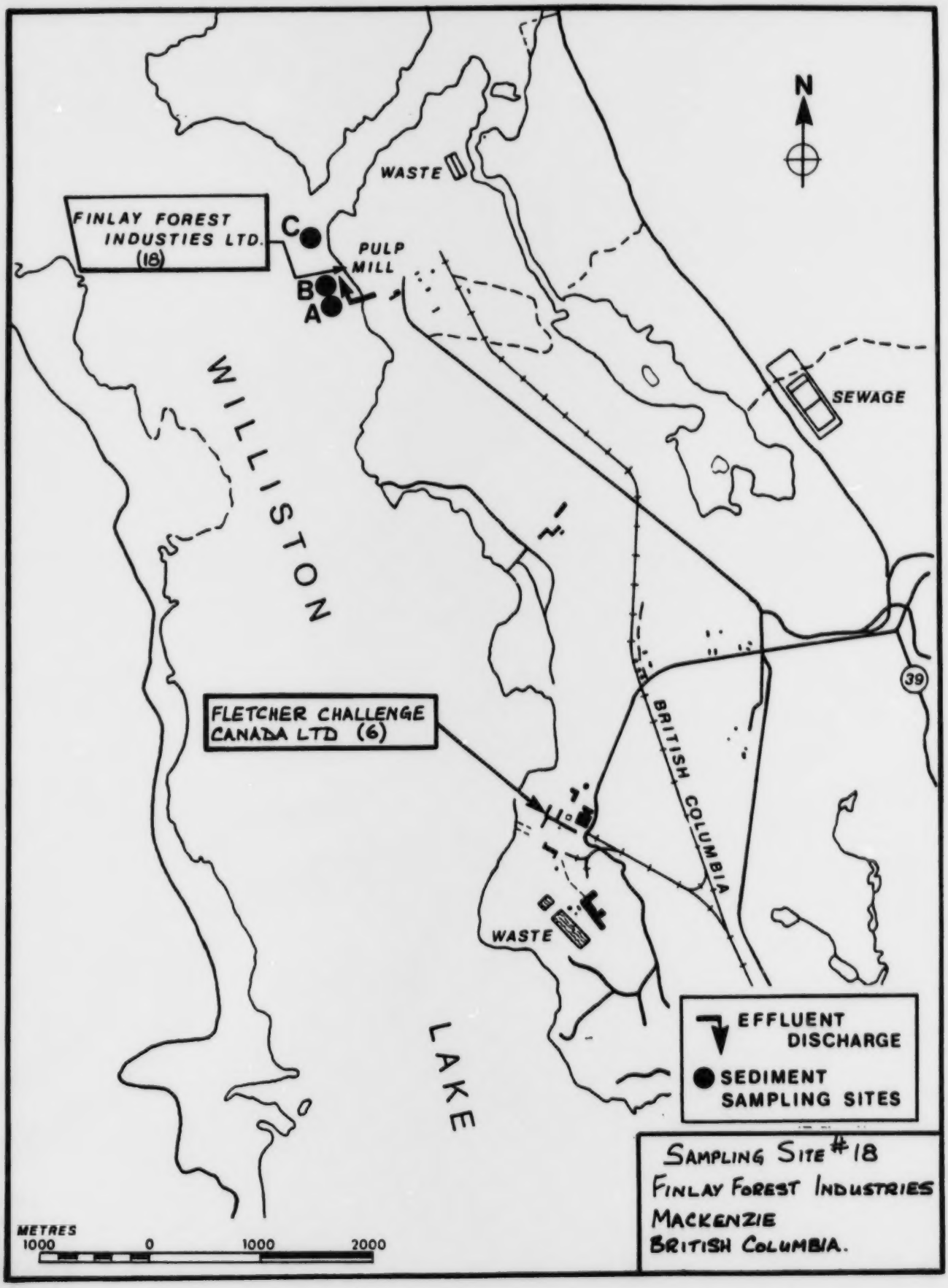

* NOTE
A,B,C APPROX 100 km UPSTREAM NEAR HANSARD
A,B,C
NORTHWOOD PULP & TIMBER CO.
97
N
SEWAGE
B.C.R.
FRASER RIVER
C.N.R.
CANFOR PRINCE GEORGE PULP & PAPER MILLS
PRINCE GEORGE PULP & INTER-CONTINENTAL PULP
NECHAKO
C.N.R.
ISLAND CACHE
RIVER
D
SEWAGE
RIVER
E
F
G
PRINCE
GEORGE
16
97
FRASER
B.C.R.
0 1000 2000 3000
METRES
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE # 12/13
CANFOR PRINCE GEORGE & PRINCE GEORGE PULP AND INTERCONTINENTAL PULP LTD.
PRINCE GEORGE
BRITISH COLUMBIA.

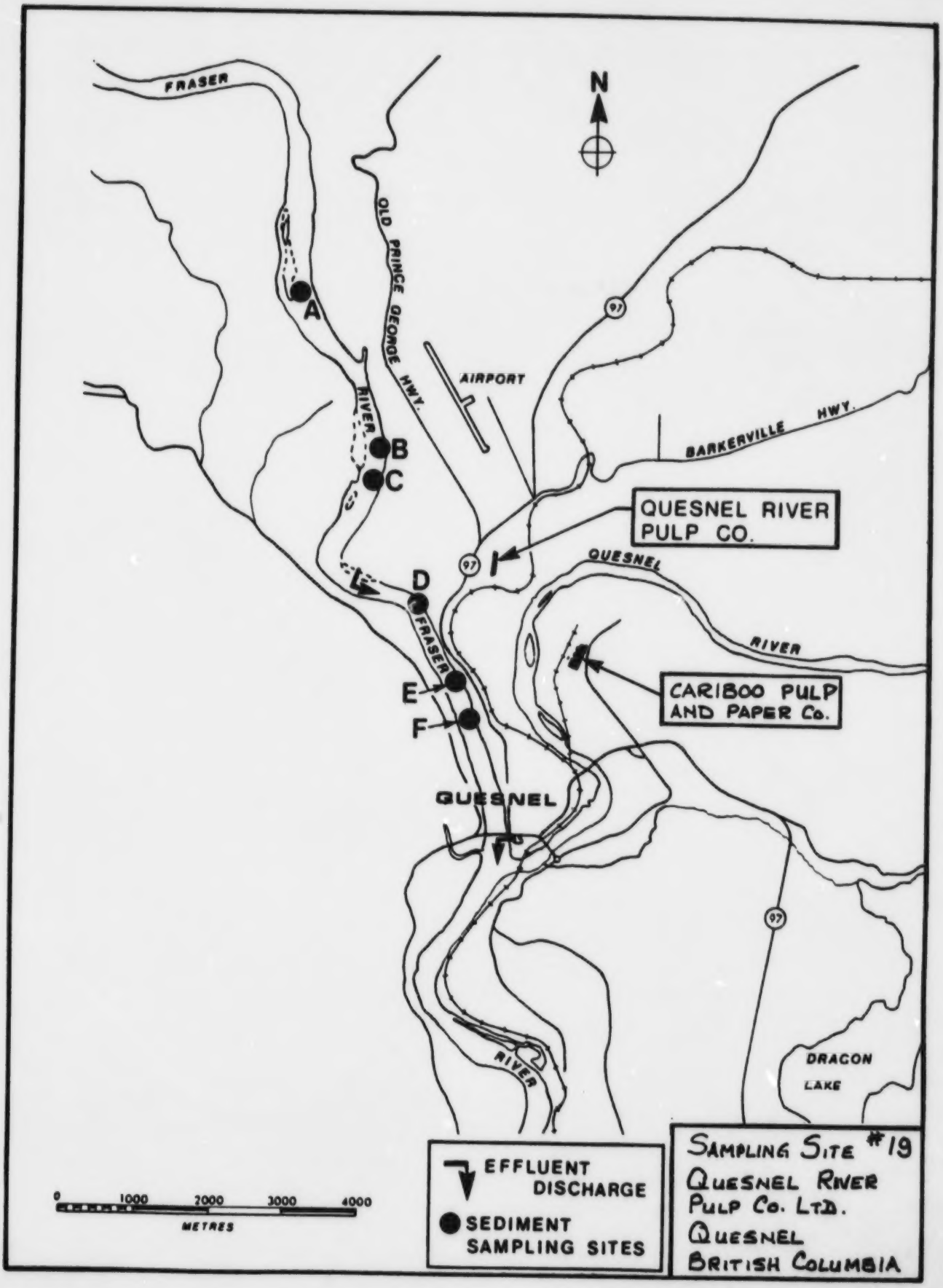

N
KAIEN ISLAND
WAINWRIGHT BASIN
WATSON ISLAND MILL
PORPOISE HARBOUR
A
B
RIDLEY ISLAND
TSIMPSEAN PENINSULA
CHATHAM SOUND
INVERNESS PASSAGE
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
0
1.0
2.0 km
SAMPLING SITE #14
SKEENA CELLULOSE INC
PRINCE RUPERT
BRITISH COLUMBIA

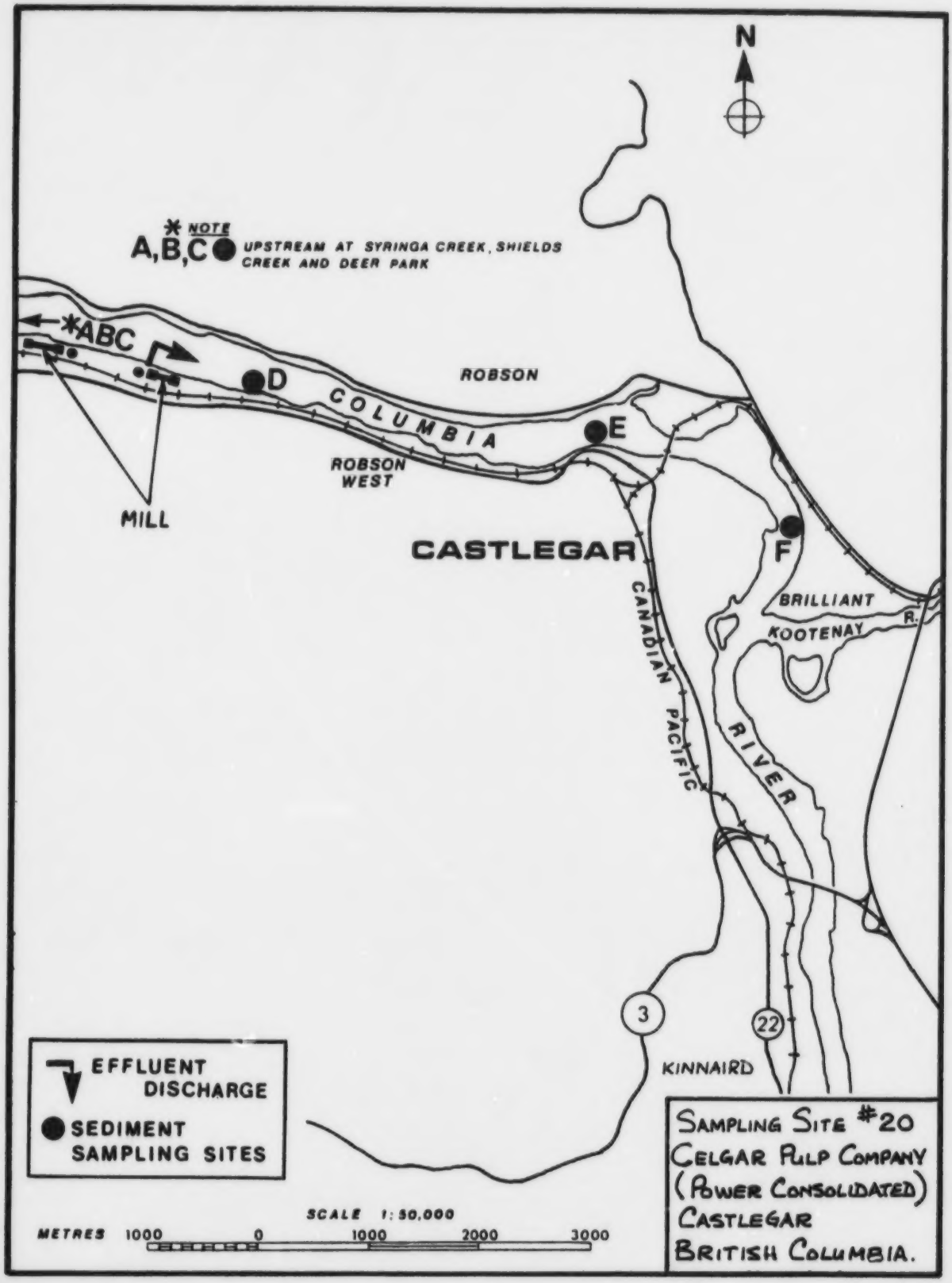

FRASER
N
OLD PRINCE GEORGE HWY.
AIRPORT
97
BARKERVILLE HWY.
RIVER
QUESNEL RIVER PULP CO.
97
QUESNEL
FRASER
RIVER
CARIBOO PULP AND PAPER CO.
QUESNEL
B
C
D
RIVER
A
97
DRACON LAKE
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
0 1000 2000 3000 4000
METRES
SAMPLING SITE #15
CARIBOO PULP & PAPER COMPANY
QUESNEL
BRITISH COLUMBIA

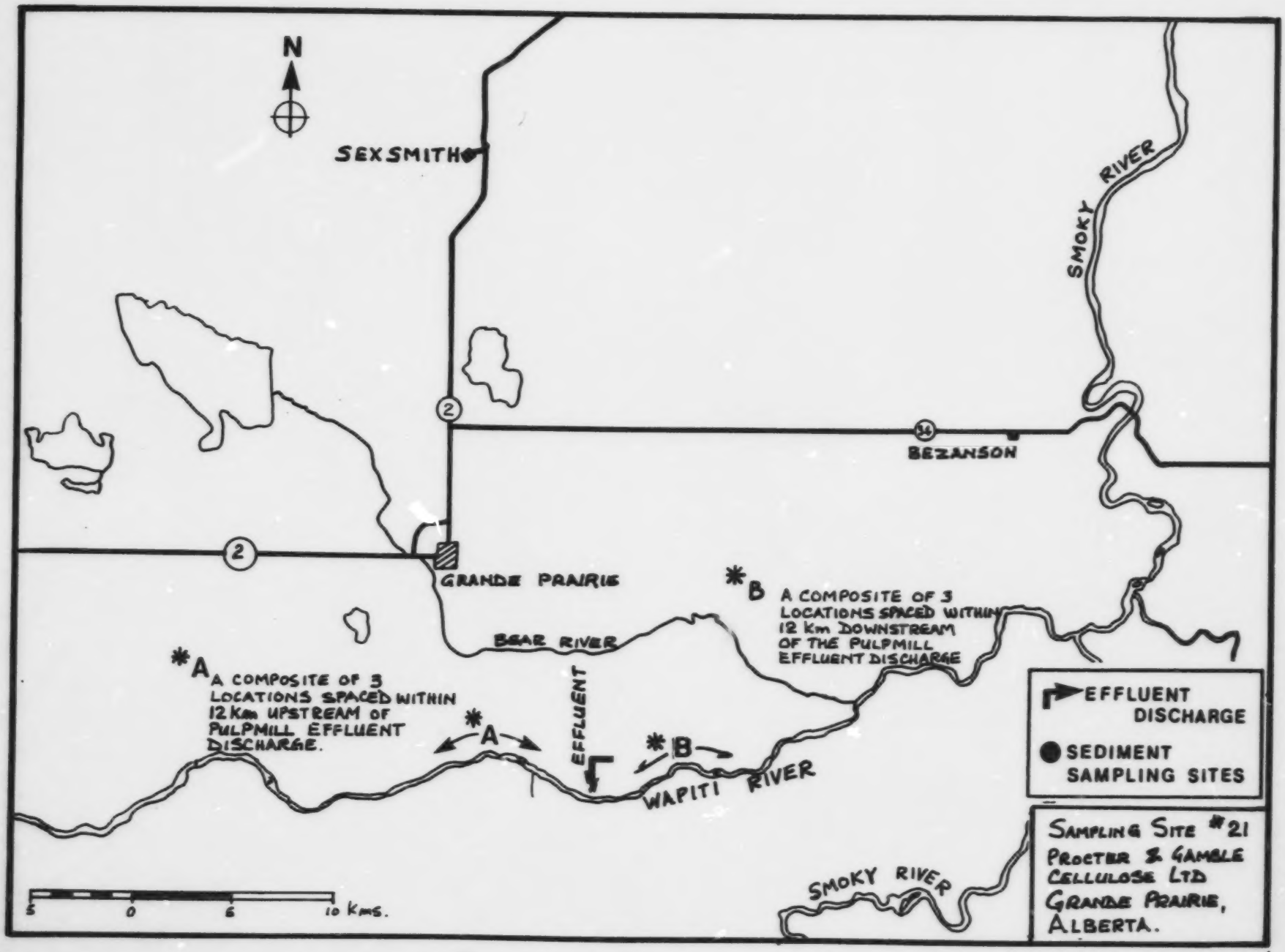

N
A
* NOTE
3 km. UPSTREAM OF CANAL FLATS
METERS
1000
0
1000
2000
KOOTENAY RIVER
CANADIAN PACIFIC
B
93
95
CRESTBROOK FOREST
INDUSTRIES LTD.
PULP DIVISION
WASTE
MILL
TAMARACK
LAKE
C
D
E
F
LUSSIER RIVER
SKOOKUMCHUCK CREEK
SKOOKUMCHUCK
EFFLUENT
DISCHARGE
SEDIMENT
SAMPLING SITES
SAMPLING SITE #16
CRESTBROOK FOREST
INDUSTRIES LTD.
CRANBROOK
BRITISH COLUMBIA

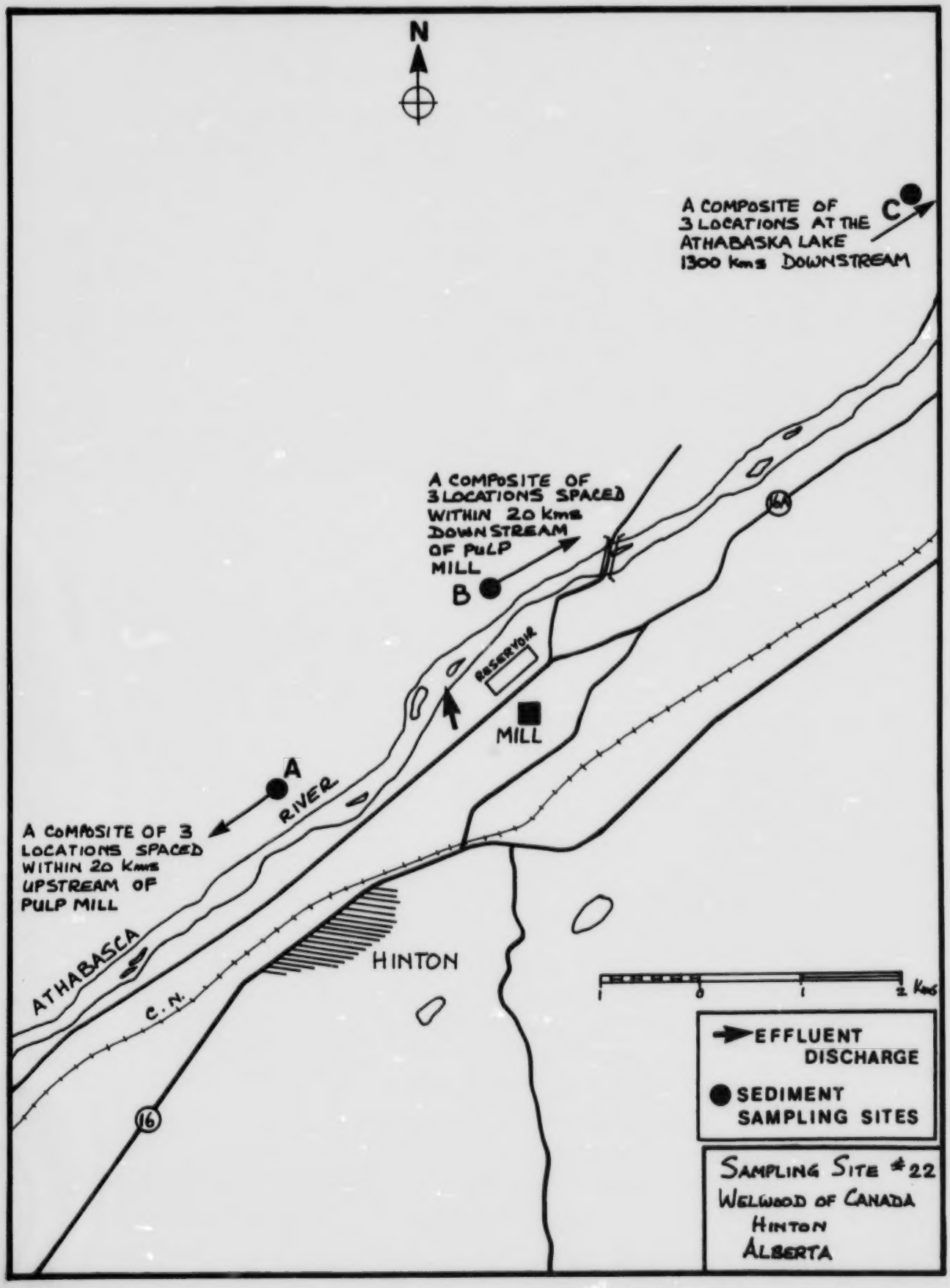

0 50 100m.
N
CHIP STORAGE
BORGE DOCK
MILL CREEK
CHIP SILOS
A
B
ADMINISTRATION
FERRY
SQUAMISH
MILL
(SEE DETAIL ABOVE)
C
N
ANVIL ISL.
PORT MELLON
GAMBIER ISLAND
HOWE SOUND
0 2 4 6 km
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
STRAIT OF GEORGIA
GIBSON'S
BOWEN ISLAND
POINT ATKINSON
SAMPLING SITE #17
WESTERN PULP PARTNERSHIP LTD
(WOOD FIBRE)
SQUAMISH
BRITISH COLUMBIA

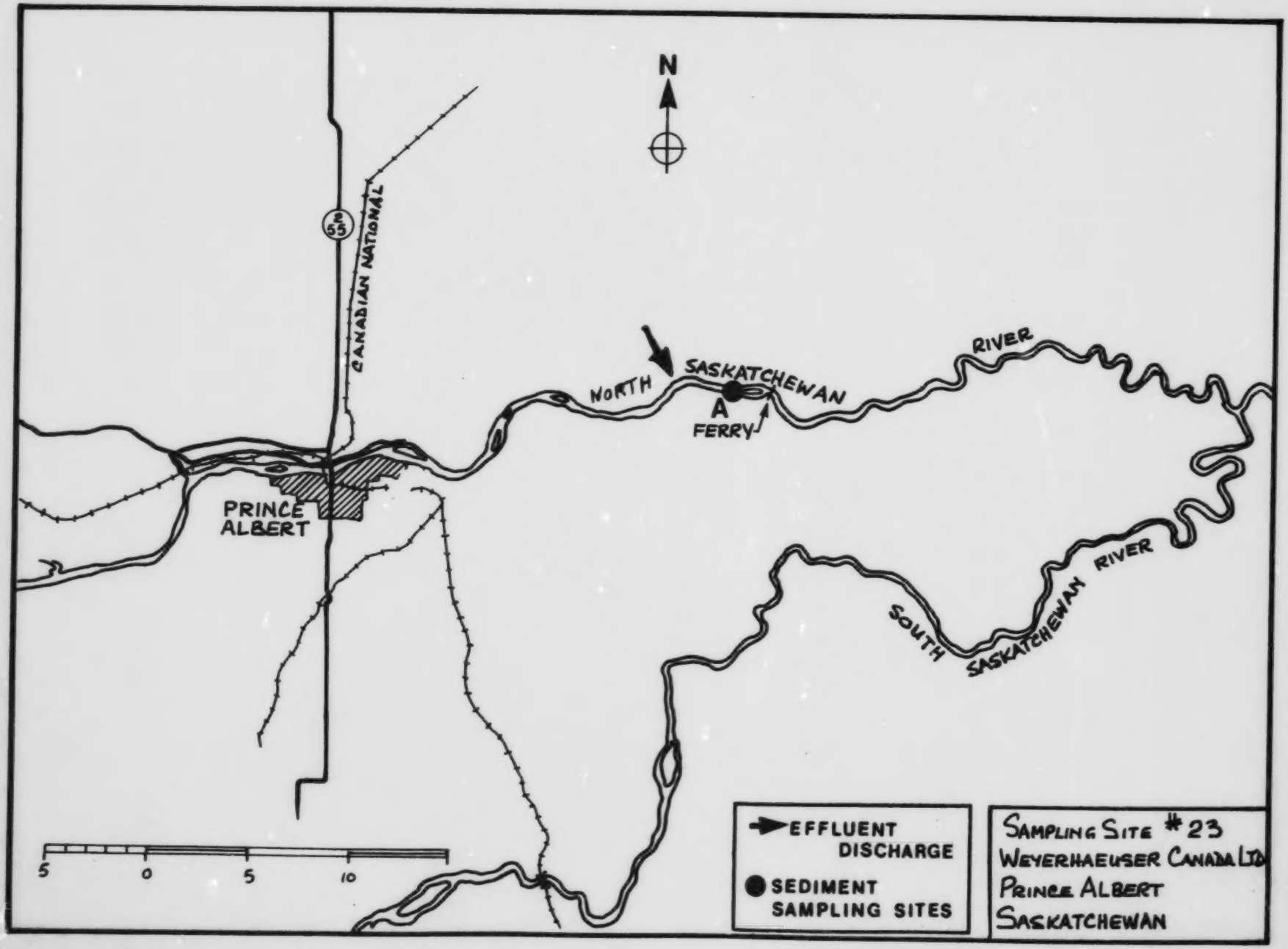

N
WASTE
FINLAY FOREST INDUSTIES LTD. (18)
C
PULP MILL
B
A
WILLISTON
SEWAGE
39
FLETCHER CHALLENGE CANADA LTD (6)
BRITISH COLUMBIA
WASTE
LAKE
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
METRES
1000
0
1000
2000
SAMPLING SITE #18
FINLAY FOREST INDUSTRIES
MACKENZIE
BRITISH COLUMBIA.

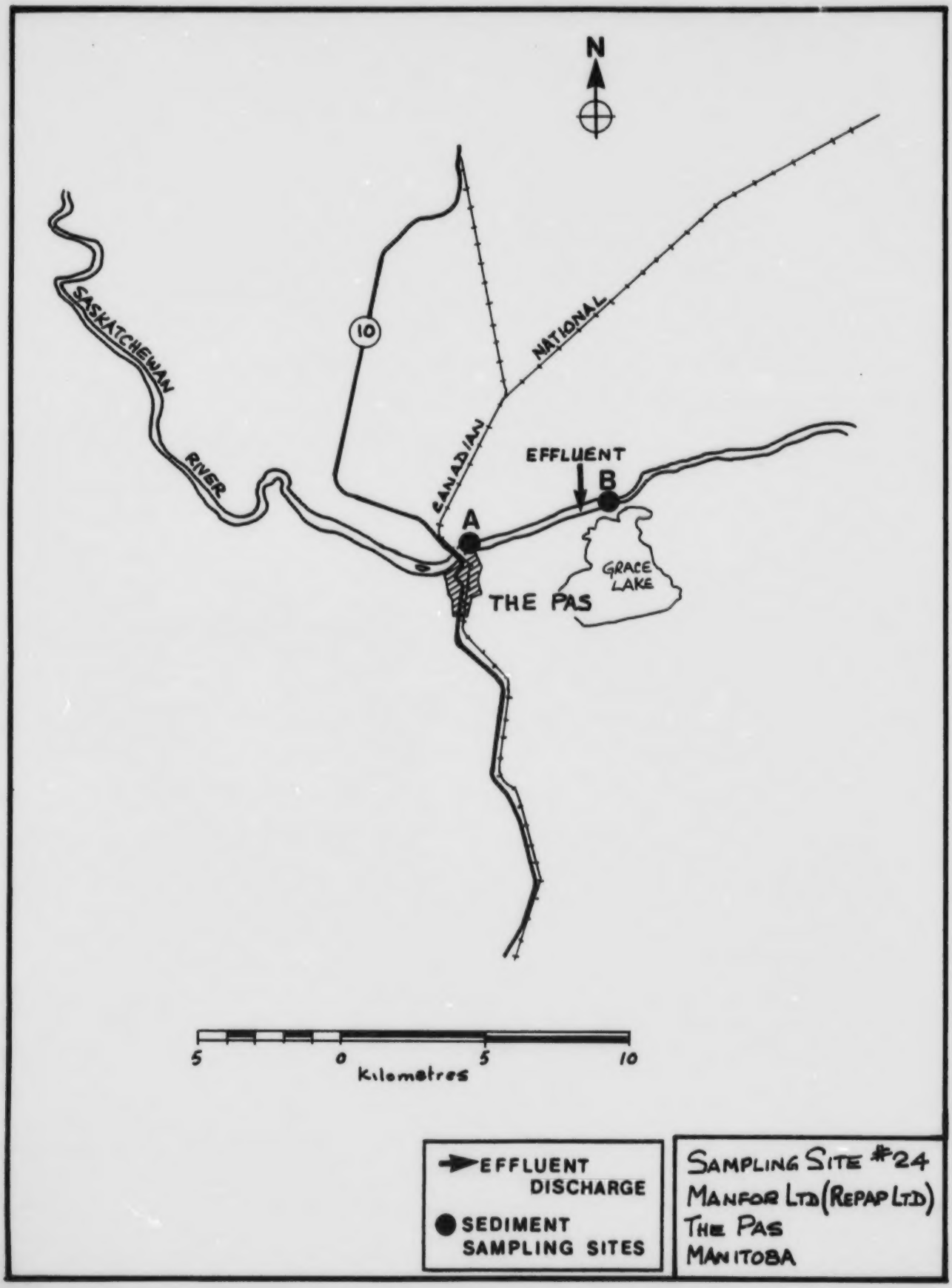

FRASER
OLD PRINCE GEORGE HWY.
N
A
AIRPORT
97
BARKERVILLE HWY.
RIVER
B
C
QUESNEL RIVER PULP CO.
97
QUESNEL
D
FRASER
RIVER
E
CARIBOO PULP AND PAPER Co.
F
QUESNEL
97
RIVER
DRAGON LAKE
0 1000 2000 3000 4000
METRES
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #19
QUESNEL RIVER PULP CO. LTD.
QUESNEL
BRITISH COLUMBIA

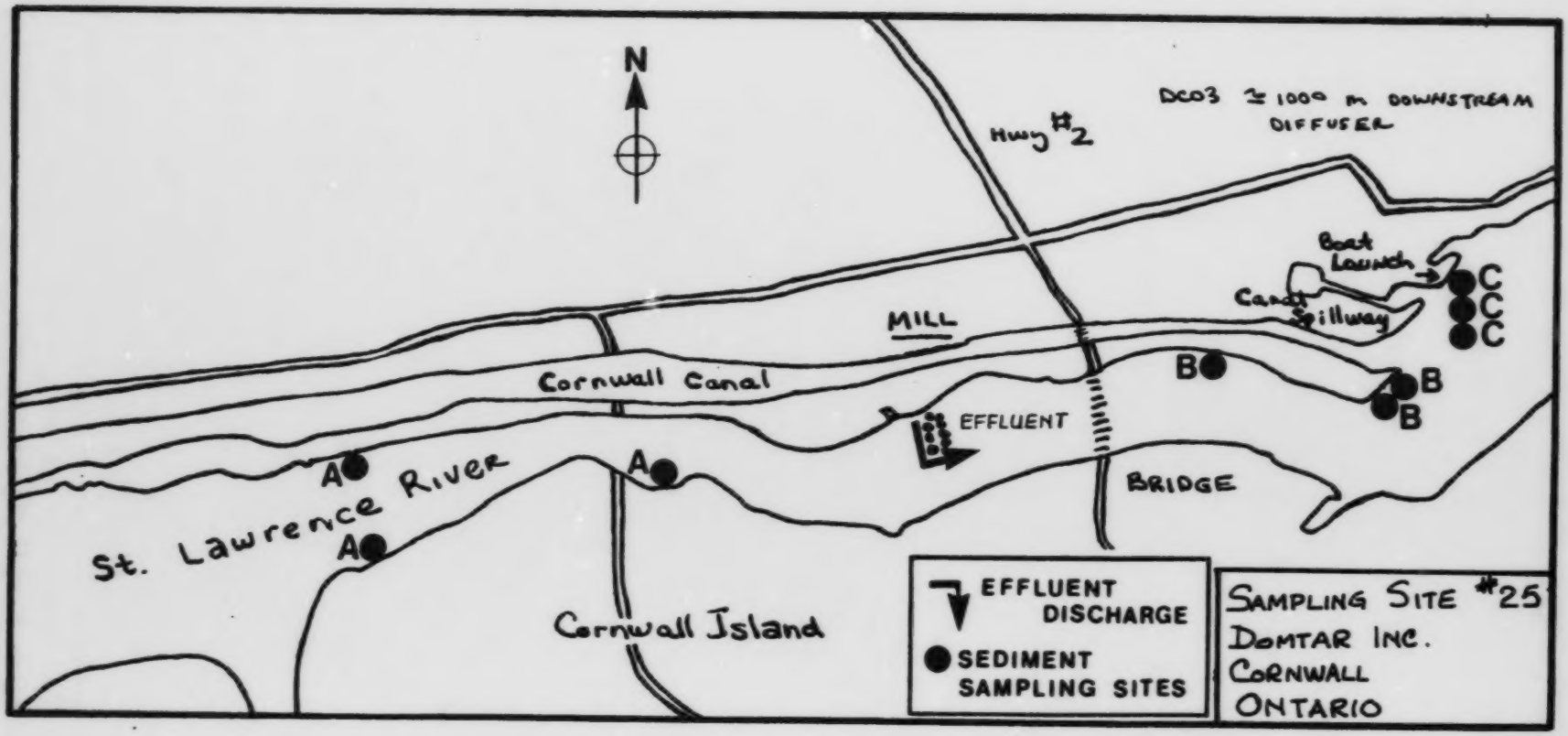

N
* NOTE
A,B,C
UPSTREAM AT SYRINGA CREEK, SHIELDS CREEK AND DEER PARK
*ABC
D
ROBSON
COLUMBIA
E
ROBSON WEST
MILL
CASTLEGAR
F
BRILLIANT
KOOTENAY R.
CANADIAN PACIFIC
RIVER
3
22
KINNAIRD
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SCALE 1:50,000
METRES 1000 0 1000 2000 3000
SAMPLING SITE #20
CELGAR PULP COMPANY
(POWER CONSOLIDATED)
CASTLEGAR
BRITISH COLUMBIA.

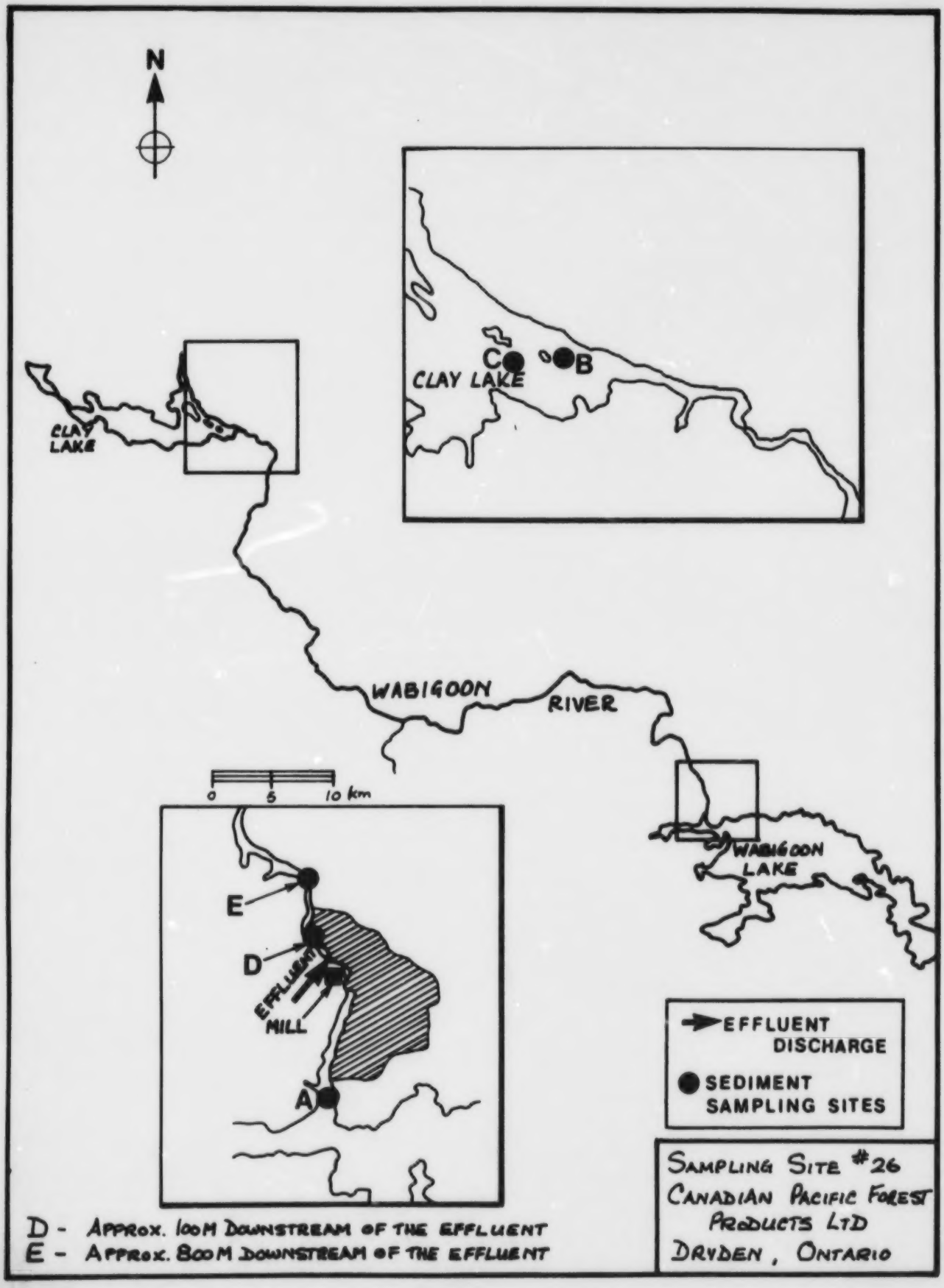

N
SEXSMITH
SMOKY RIVER
2
34
BEZANSON
2
GRANDE PRAIRIE
*B
A COMPOSITE OF 3 LOCATIONS SPACED WITHIN 12 Km DOWNSTREAM OF THE PULPMILL EFFLUENT DISCHARGE
BEAR RIVER
*A
A COMPOSITE OF 3 LOCATIONS SPACED WITHIN 12 Km UPSTREAM OF PULPMILL EFFLUENT DISCHARGE.
*A
EFFLUENT
*B
WAPITI RIVER
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #21
PROCTER & GAMBLE CELLULOSE LTD
GRANDE PRAIRIE, ALBERTA.
SMOKY RIVER
5 0 5 10 Kms.

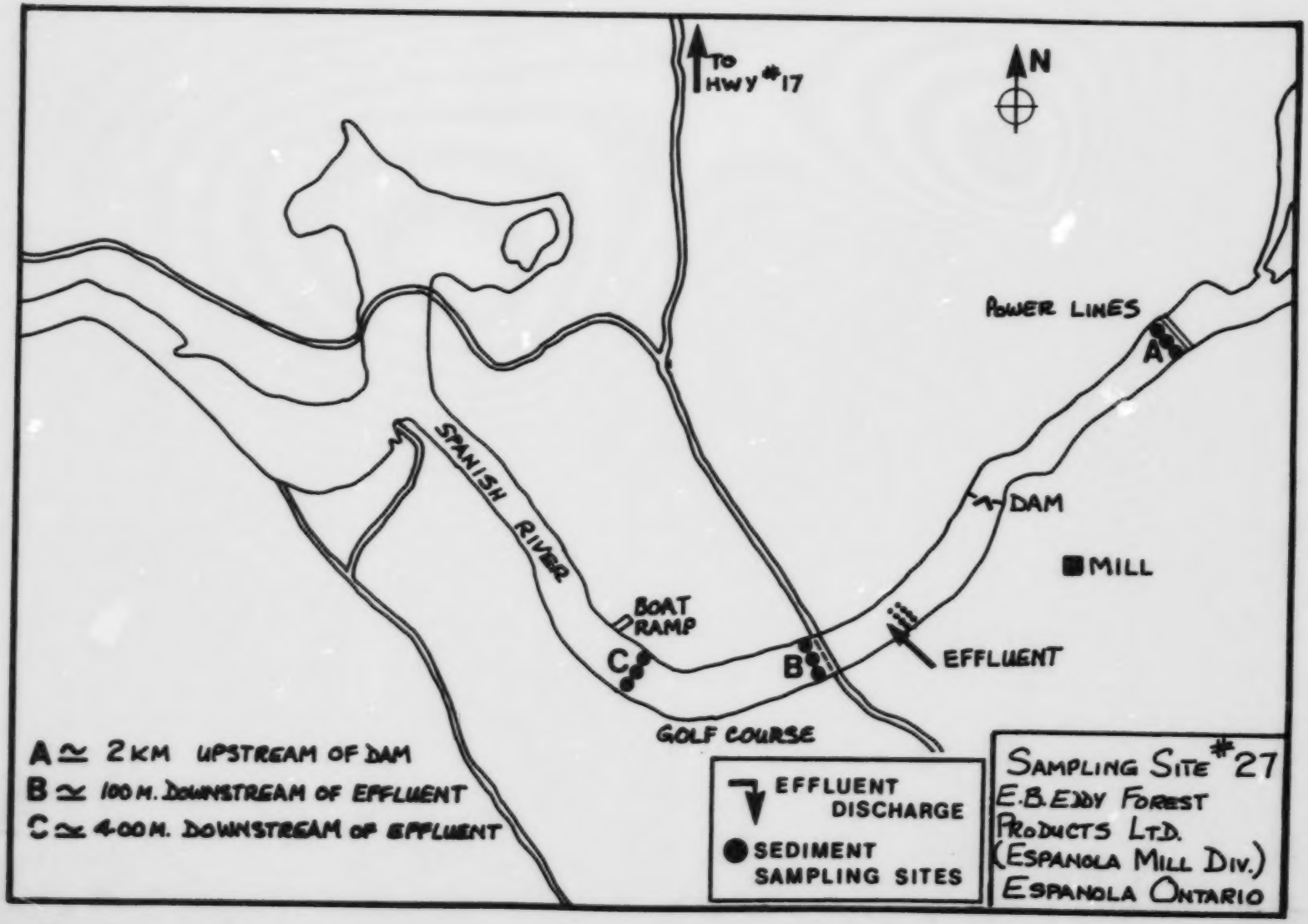

N
A COMPOSITE OF 3 LOCATIONS AT THE ATHABASKA LAKE 1300 kms DOWNSTREAM
C
A COMPOSITE OF 3 LOCATIONS SPACED WITHIN 20 kms DOWNSTREAM OF PULP MILL
B
16A
RESERVOIR
MILL
A
RIVER
A COMPOSITE OF 3 LOCATIONS SPACED WITHIN 20 kms UPSTREAM OF PULP MILL
ATHABASCA
C.N.
HINTON
16
1 0 1 2 kms
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #22
WELDWOOD OF CANADA
HINTON
ALBERTA

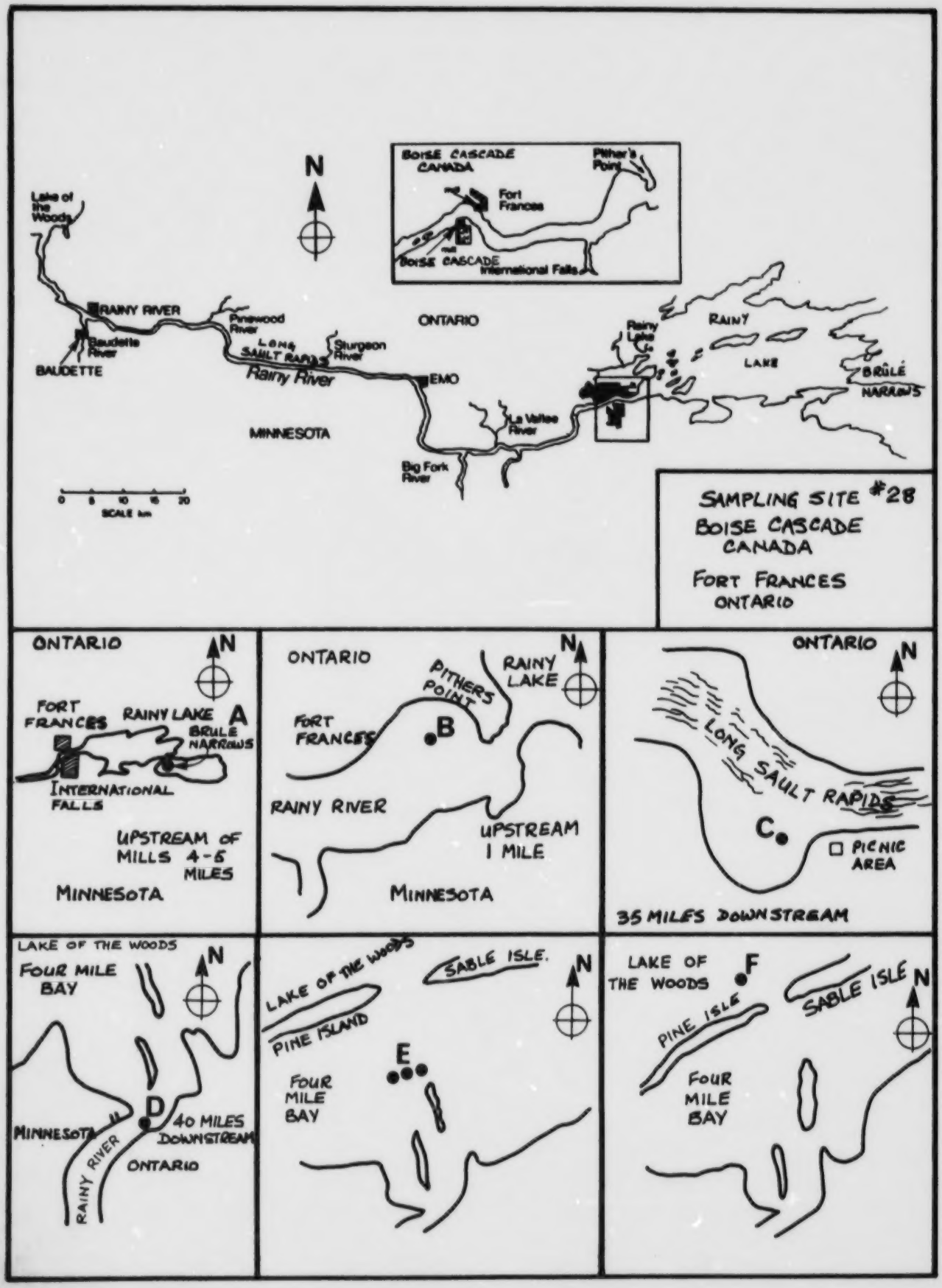

N
CANADIAN NATIONAL
55
NORTH SASKATCHEWAN RIVER
A
FERRY
PRINCE ALBERT
SOUTH SASKATCHEWAN RIVER
5 0 5 10
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #23
WEYERHAEUSER CANADA LTD
PRINCE ALBERT
SASKATCHEWAN

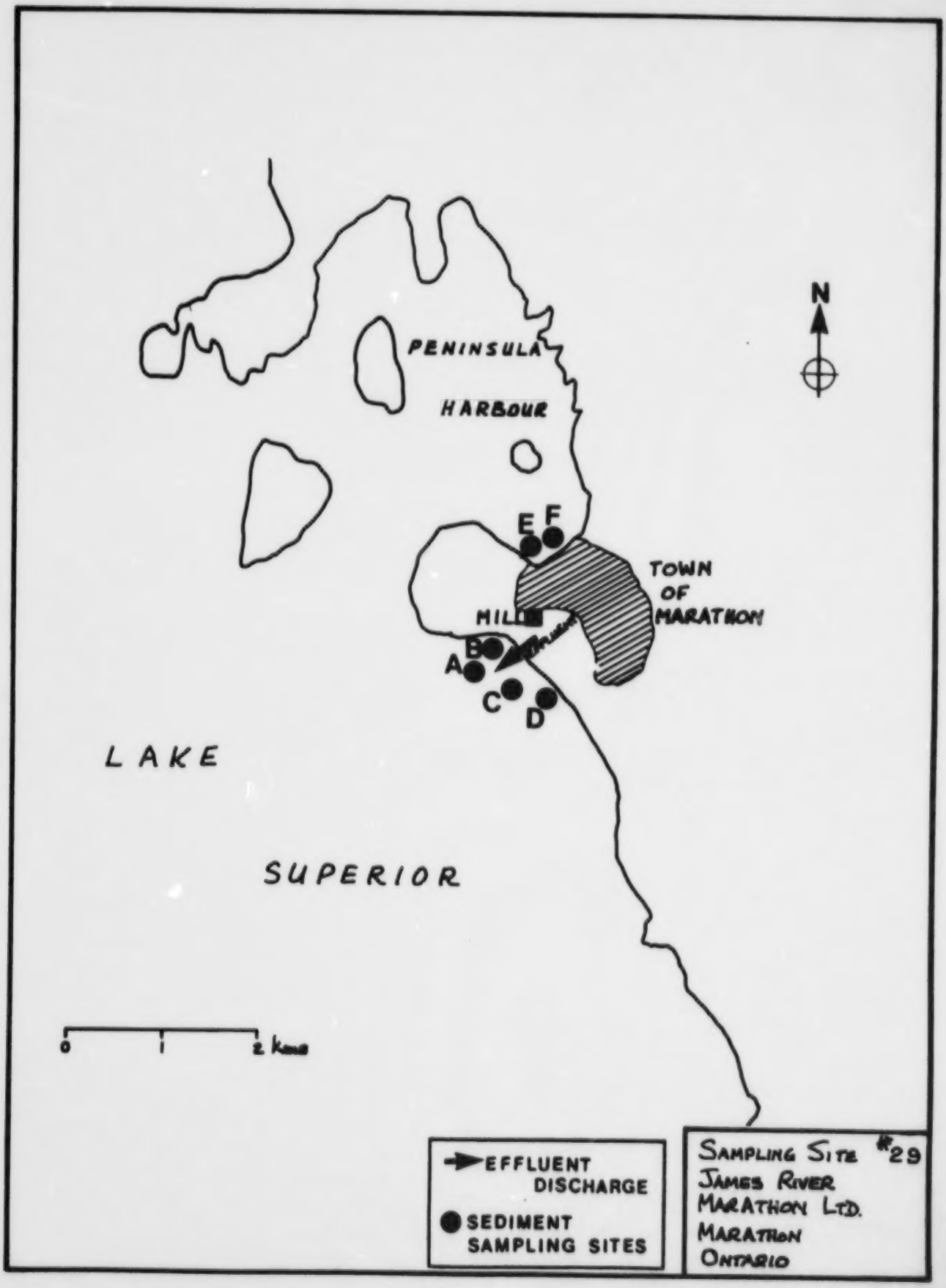

N
SASKATCHEWAN
RIVER
10
CANADIAN
NATIONAL
EFFLUENT
B
A
GRACE
LAKE
THE PAS
5
0
5
10
Kilometres
EFFLUENT
DISCHARGE
SEDIMENT
SAMPLING SITES
SAMPLING SITE #24
MANFOR LTD (REPAP LTD)
THE PAS
MANITOBA

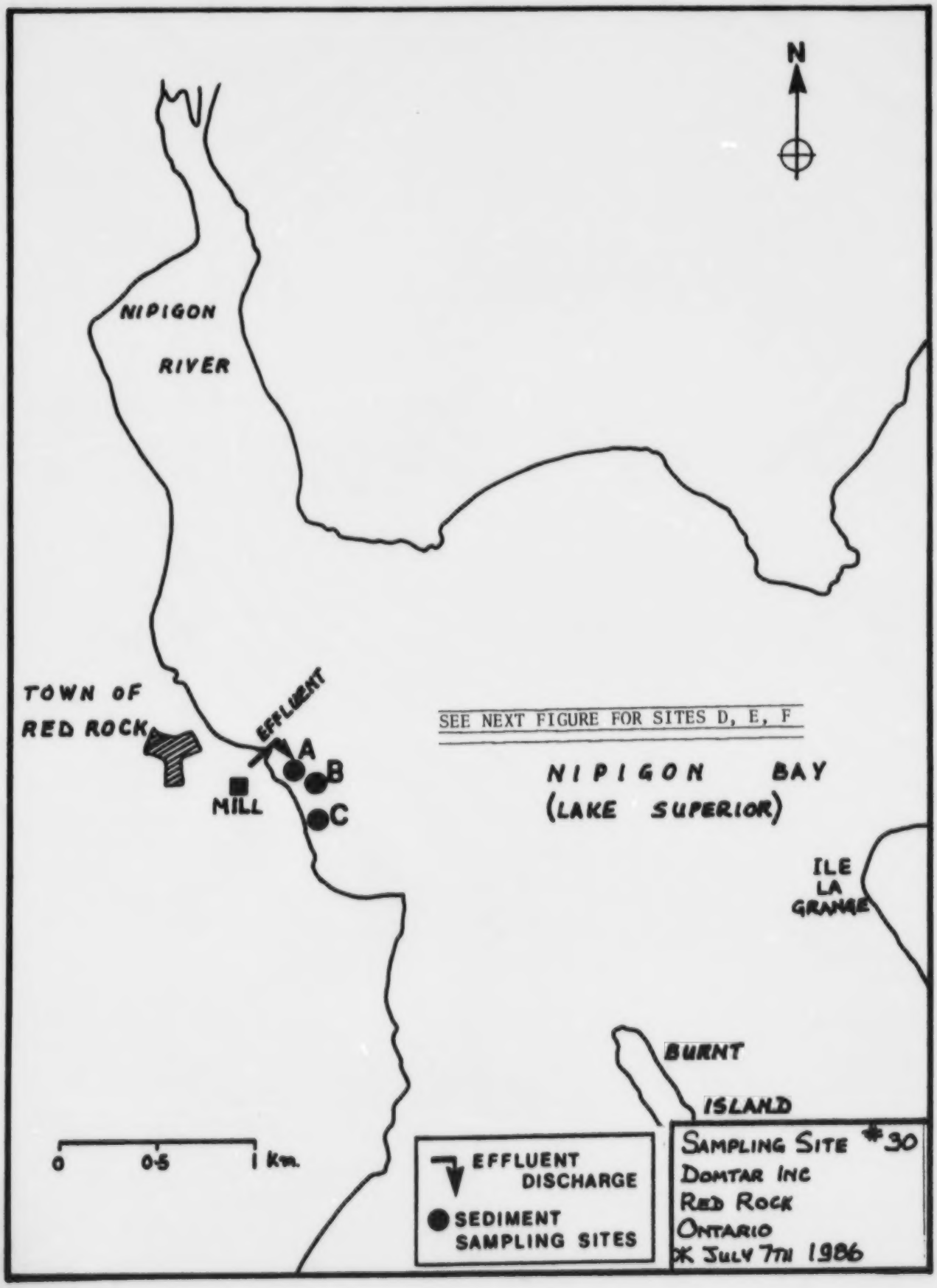

N
Hwy #2
DC03 ± 1000 m DOWNSTREAM
DIFFUSER
Boat Launch
Canal Spillway
C
C
C
MILL
Cornwall Canal
B
B
B
EFFLUENT
A
A
A
St. Lawrence River
BRIDGE
Cornwall Island
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #25
DOMTAR INC.
CORNWALL
ONTARIO

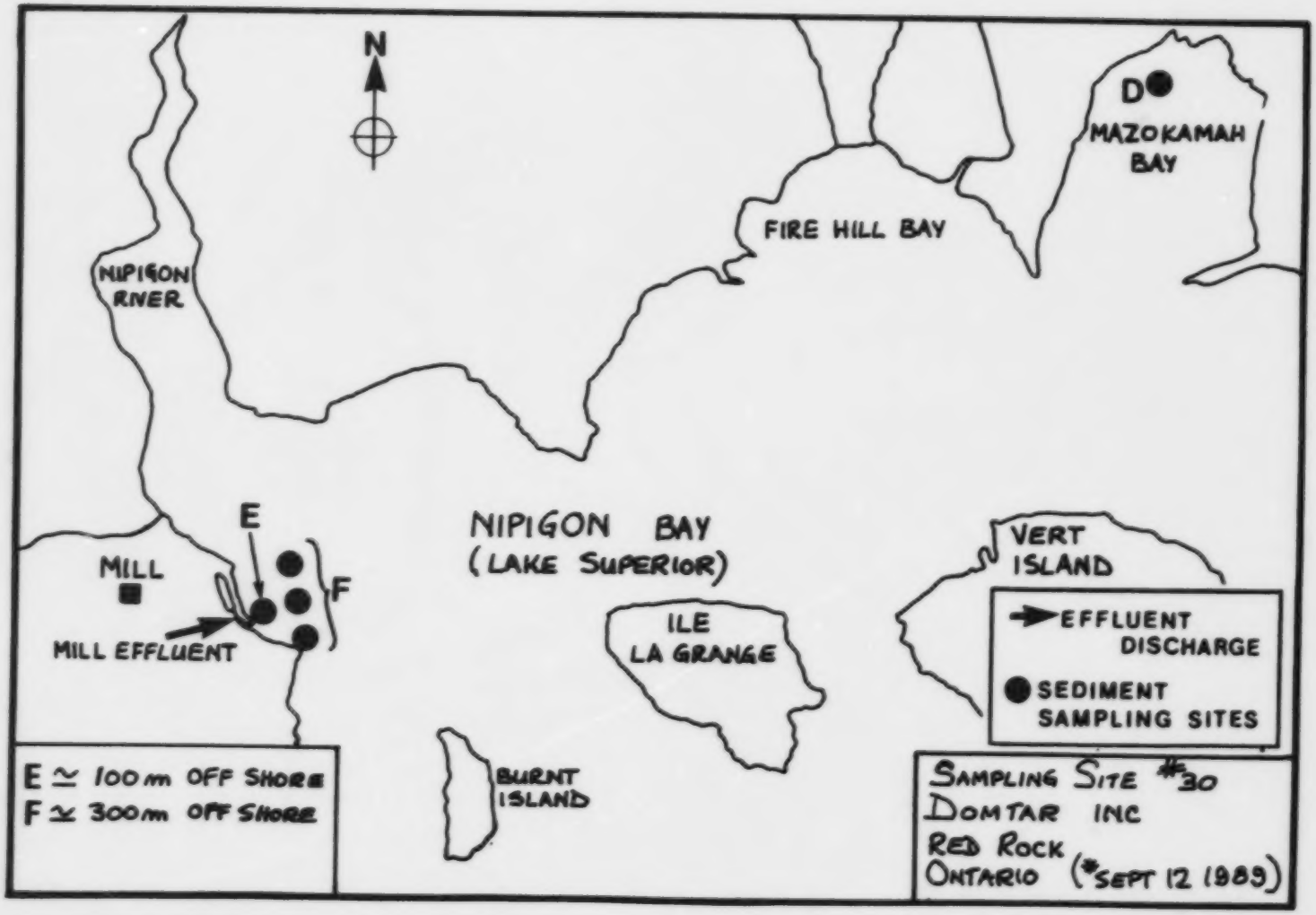

N
CLAY LAKE
C
B
CLAY LAKE
WABIGOON RIVER
0 5 10 km
WABIGOON LAKE
E
D
EFFLUENT
MILL
A
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #26
CANADIAN PACIFIC FOREST PRODUCTS LTD
DRYDEN, ONTARIO
D - APPROX. 100M DOWNSTREAM OF THE EFFLUENT
E - APPROX. 800M DOWNSTREAM OF THE EFFLUENT

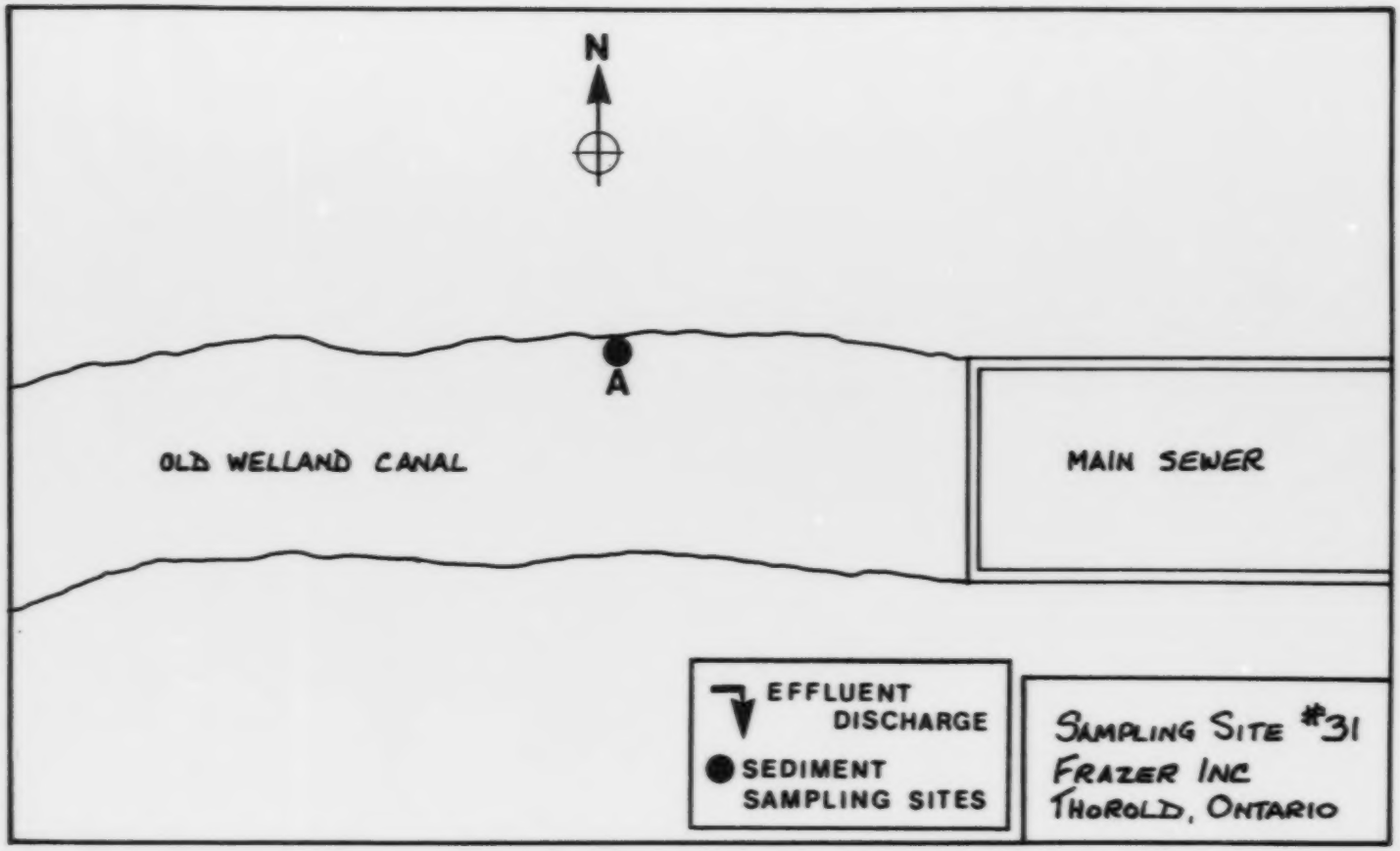

TO HWY #17
N
POWER LINES
A
DAM
MILL
SPANISH RIVER
BOAT RAMP
C
B
EFFLUENT
GOLF COURSE
A ≃ 2 KM UPSTREAM OF DAM
B ≃ 100 M. DOWNSTREAM OF EFFLUENT
C ≃ 400 M. DOWNSTREAM OF EFFLUENT
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #27
E.B. EDDY FOREST PRODUCTS LTD.
(ESPANOLA MILL DIV.)
ESPANOLA ONTARIO

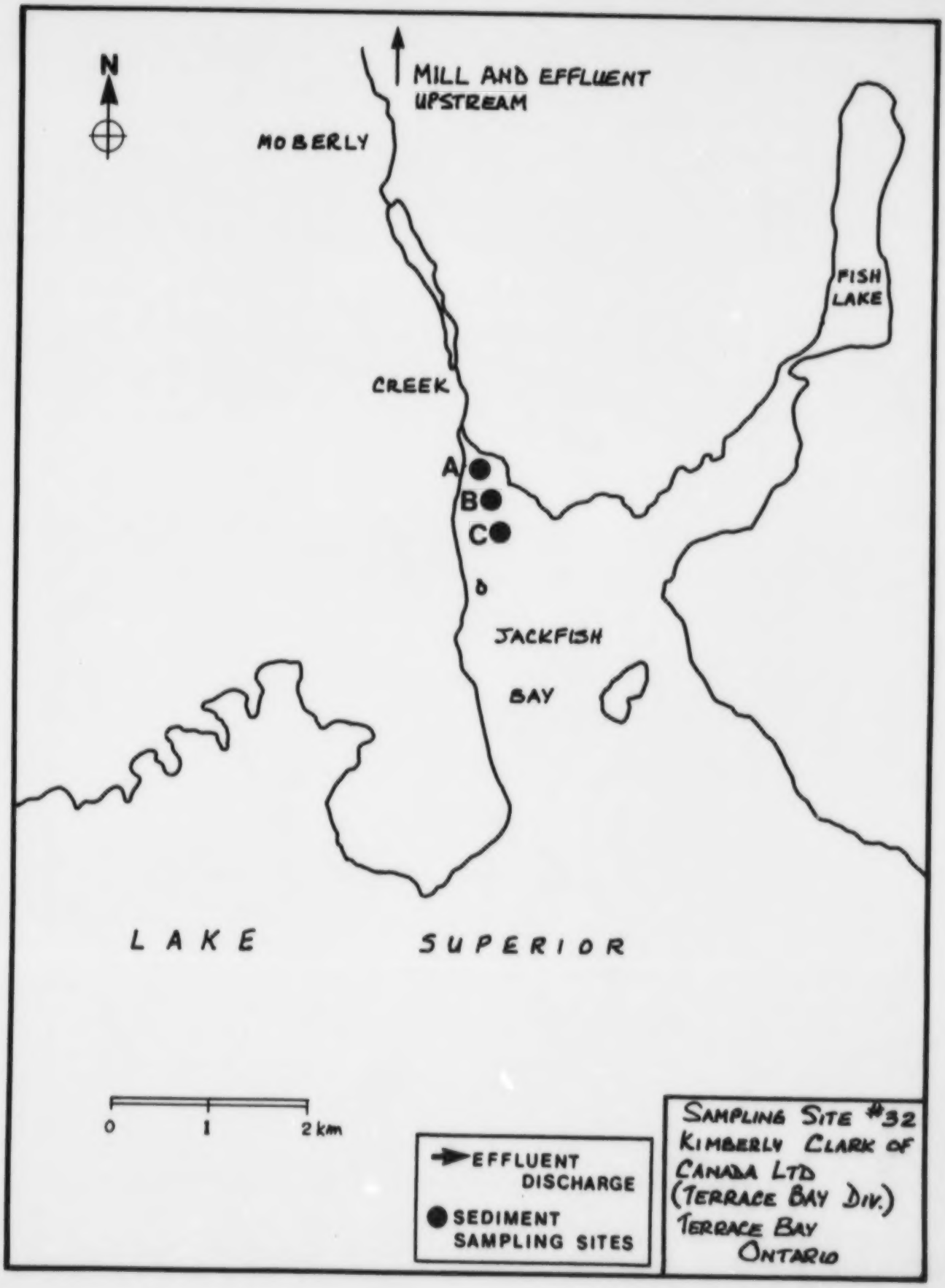

N
Boise Cascade Canada
Pither's Point
Fort Frances
O.P.
Rail
Boise Cascade
International Falls
Lake of the Woods
RAINY RIVER
Pinewood River
Baudette River
BAUDETTE
LONG SAULT RAPIDS
Sturgeon River
Rainy River
EMO
ONTARIO
MINNESOTA
La Vallee River
Big Fork River
Rainy Lake
RAINY LAKE
BRULÉ NARROWS
0 5 10 15 20
SCALE km
SAMPLING SITE #28
BOISE CASCADE CANADA
FORT FRANCES ONTARIO
ONTARIO
N
FORT FRANCES
RAINY LAKE
A
BRULÉ NARROWS
INTERNATIONAL FALLS
UPSTREAM OF MILLS 4-5 MILES
MINNESOTA
ONTARIO
N
PITHERS POINT
RAINY LAKE
FORT FRANCES
B
RAINY RIVER
UPSTREAM 1 MILE
MINNESOTA
ONTARIO
N
LONG SAULT RAPIDS
C
PICNIC AREA
35 MILES DOWNSTREAM
LAKE OF THE WOODS
FOUR MILE BAY
N
D
MINNESOTA
40 MILES DOWNSTREAM
RAINY RIVER
ONTARIO
LAKE OF THE WOODS
SABLE ISLE.
N
PINE ISLAND
E
FOUR MILE BAY
LAKE OF THE WOODS
F
SABLE ISLE
N
PINE ISLE
FOUR MILE BAY

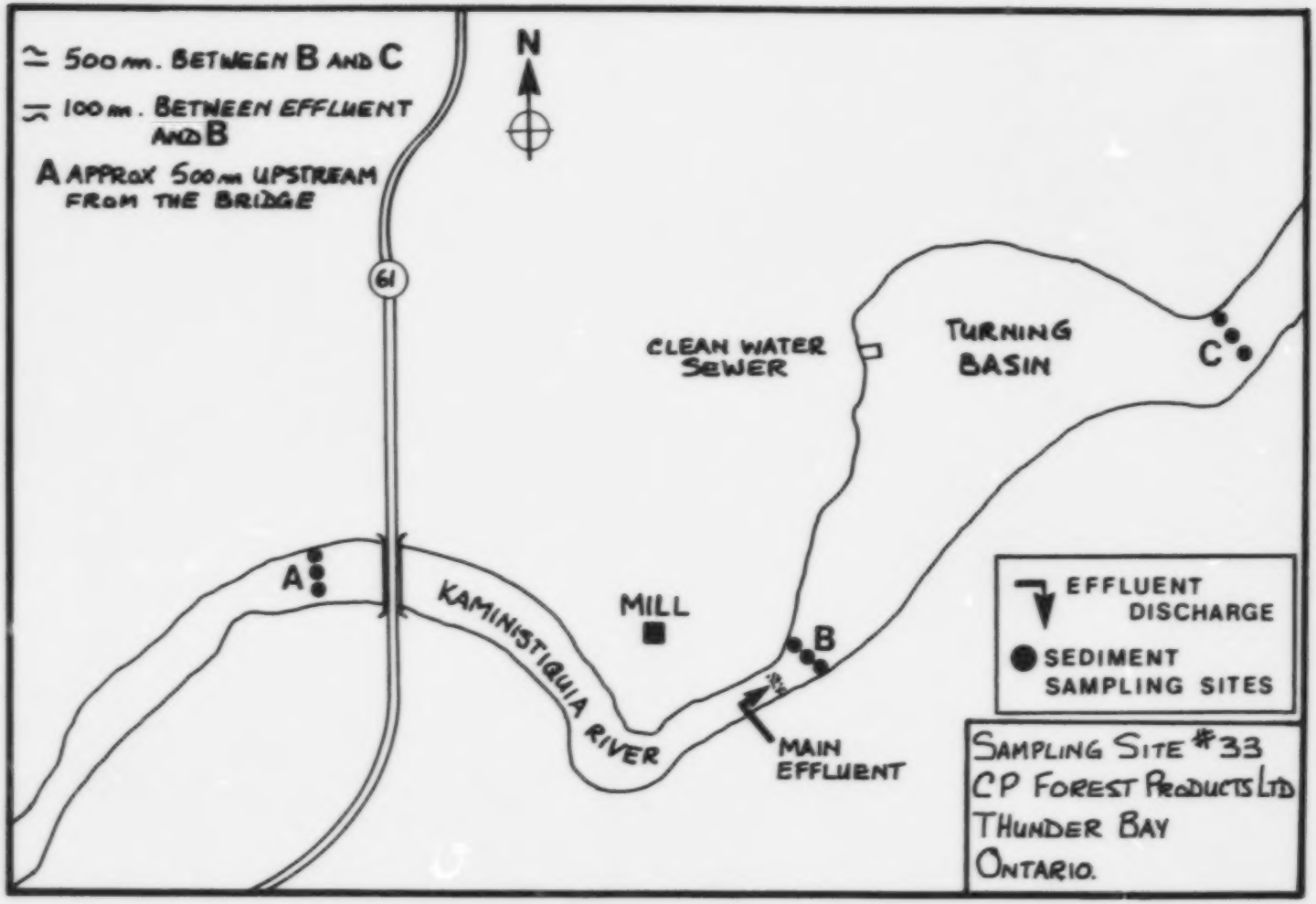

PENINSULA
HARBOUR
N
E
F
TOWN
OF
MARATHON
MILL
B
A
C
D
LAKE
SUPERIOR
0
1
2 kms
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #29
JAMES RIVER
MARATHON LTD.
MARATHON
ONTARIO

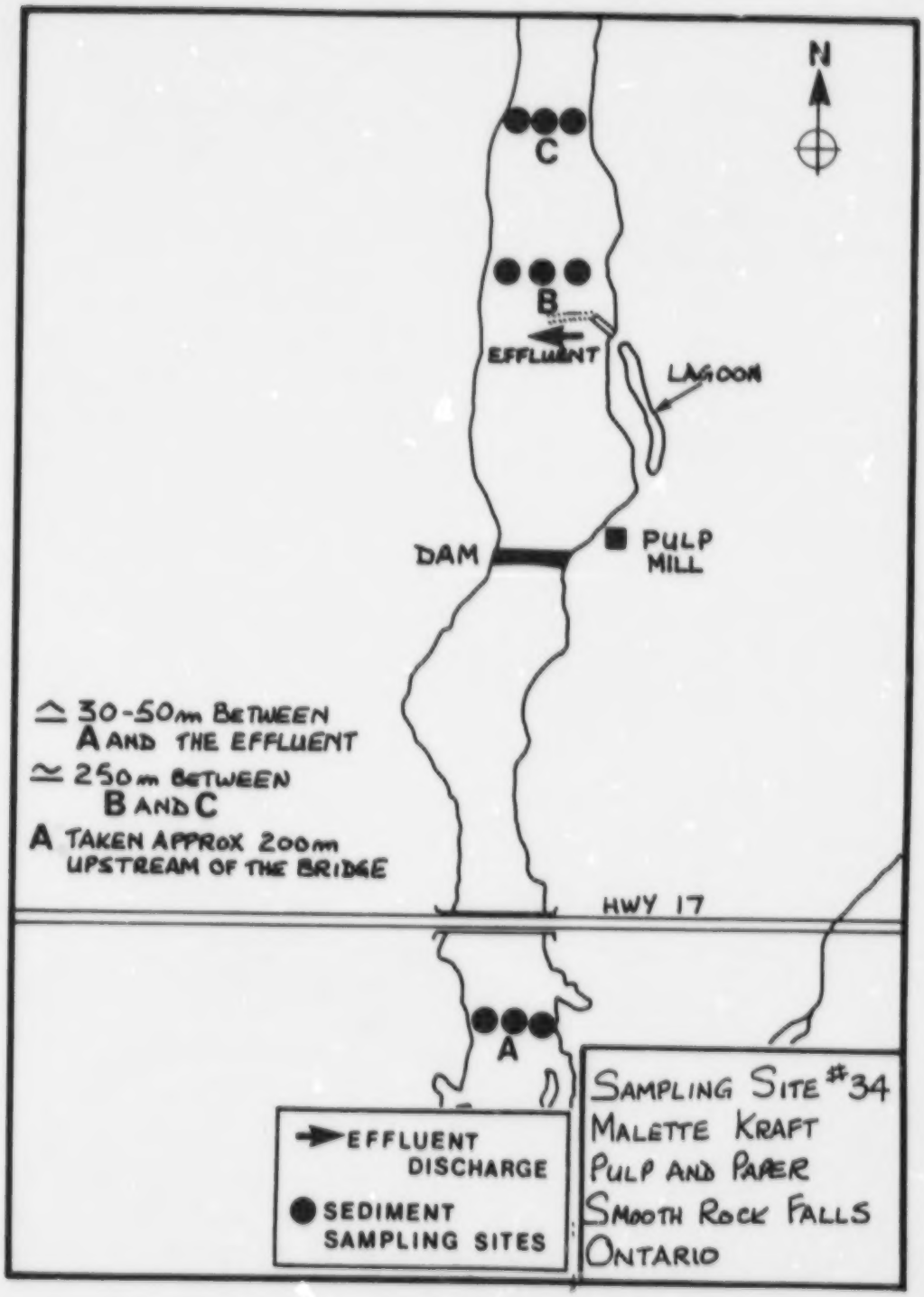

N
NIPIGON
RIVER
TOWN OF
RED ROCK
EFFLUENT
A
B
C
MILL
SEE NEXT FIGURE FOR SITES D, E, F
NIPIGON BAY
(LAKE SUPERIOR)
ILE
LA
GRANGE
BURNT
ISLAND
0
0·5
1 Km.
EFFLUENT
DISCHARGE
SEDIMENT
SAMPLING SITES
SAMPLING SITE #30
DOMTAR INC
RED ROCK
ONTARIO
JULY 7TH 1986

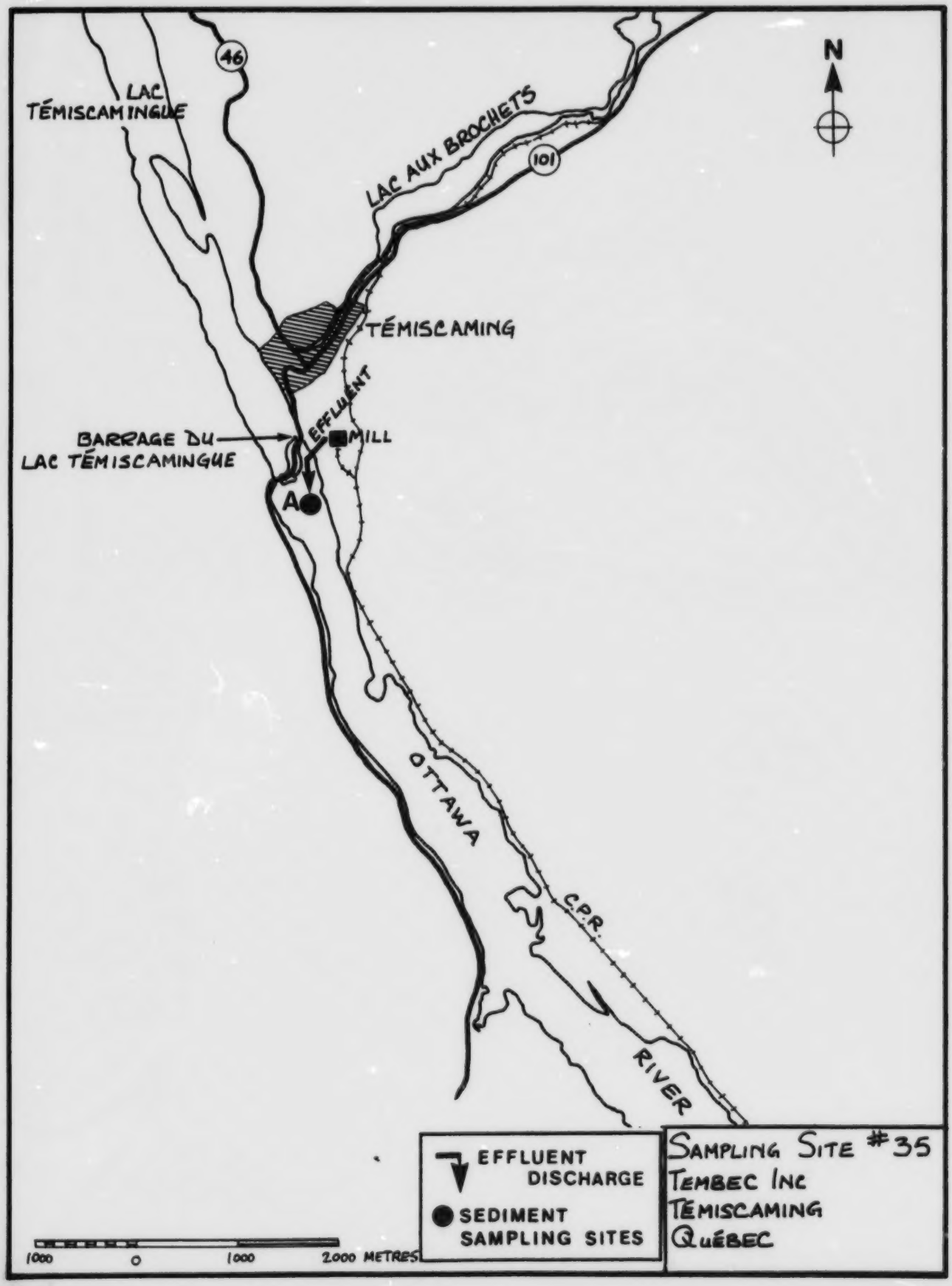

N
D
MAZOKAMAH BAY
FIRE HILL BAY
NIPIGON RIVER
E
F
MILL
MILL EFFLUENT
NIPIGON BAY (LAKE SUPERIOR)
ILE LA GRANGE
VERT ISLAND
BURNT ISLAND
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
E ≃ 100m OFF SHORE
F ≃ 300m OFF SHORE
SAMPLING SITE #30
DOMTAR INC
RED ROCK ONTARIO (*SEPT 12 1989)

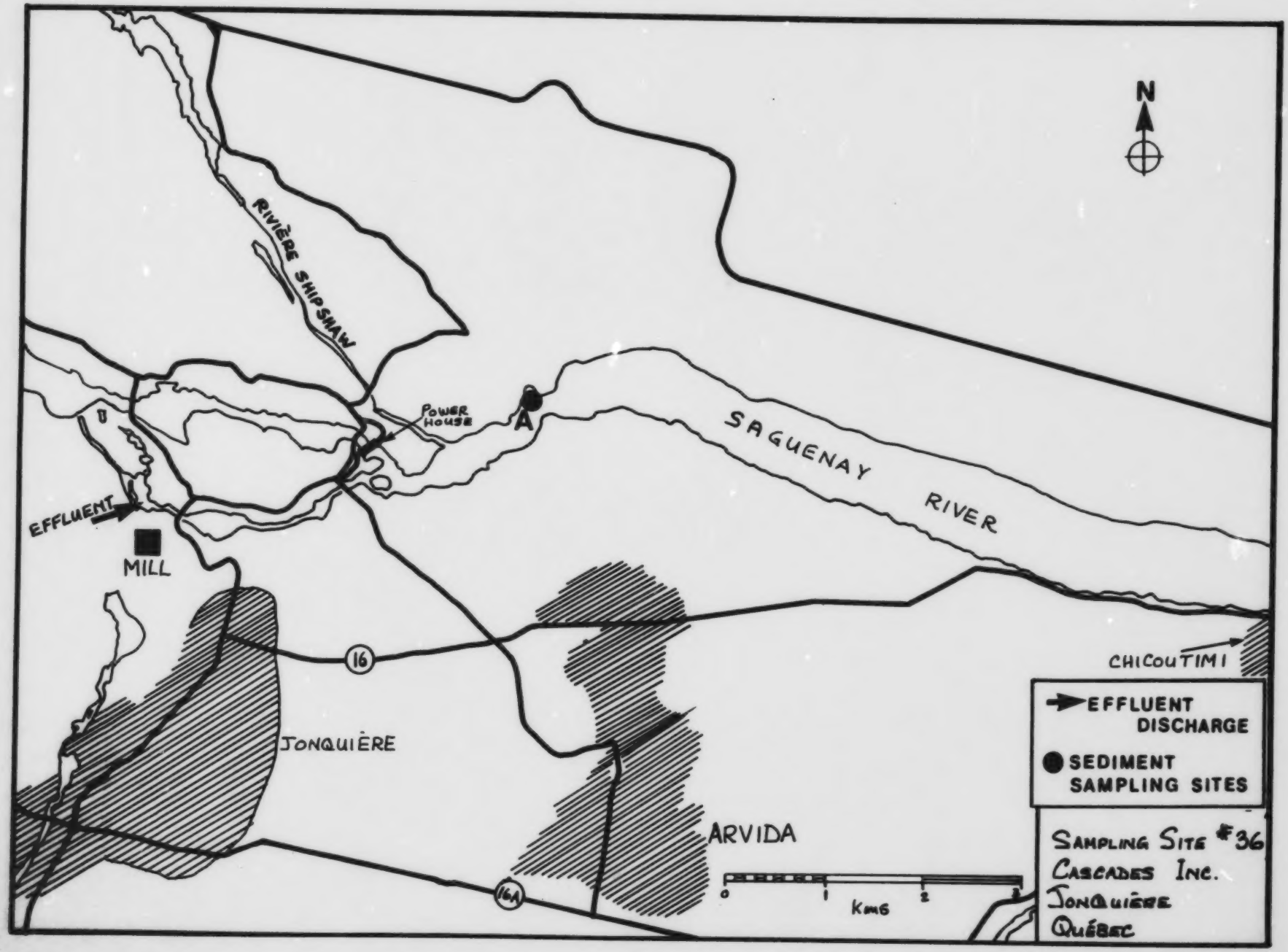

N
A
OLD WELLAND CANAL
MAIN SEWER
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #31
FRAZER INC
THOROLD, ONTARIO

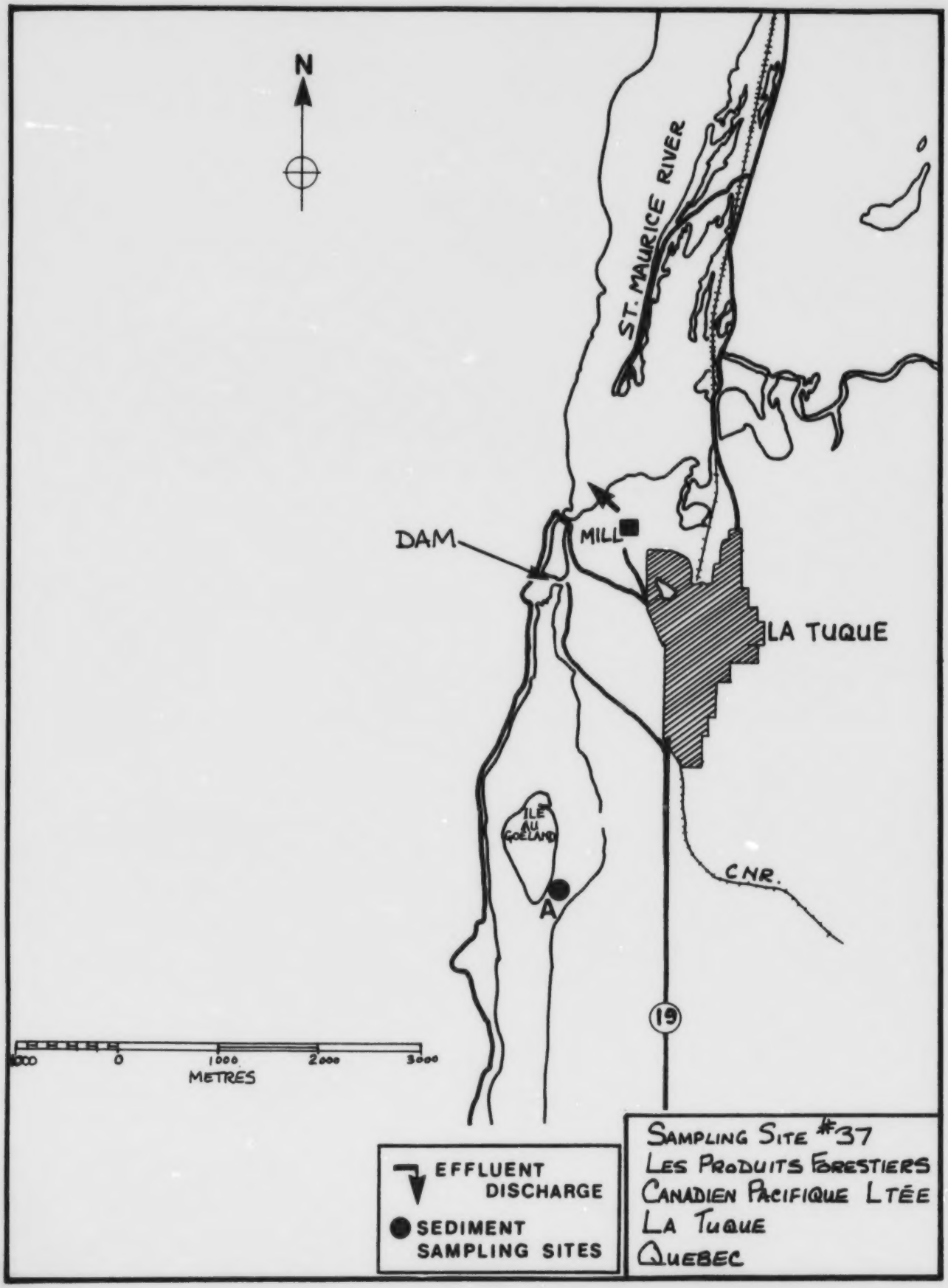

N
MILL AND EFFLUENT
UPSTREAM
MOBERLY
FISH
LAKE
CREEK
A
B
C
JACKFISH
BAY
LAKE
SUPERIOR
0
1
2 km
EFFLUENT
DISCHARGE
SEDIMENT
SAMPLING SITES
SAMPLING SITE #32
KIMBERLY CLARK OF
CANADA LTD
(TERRACE BAY DIV.)
TERRACE BAY
ONTARIO

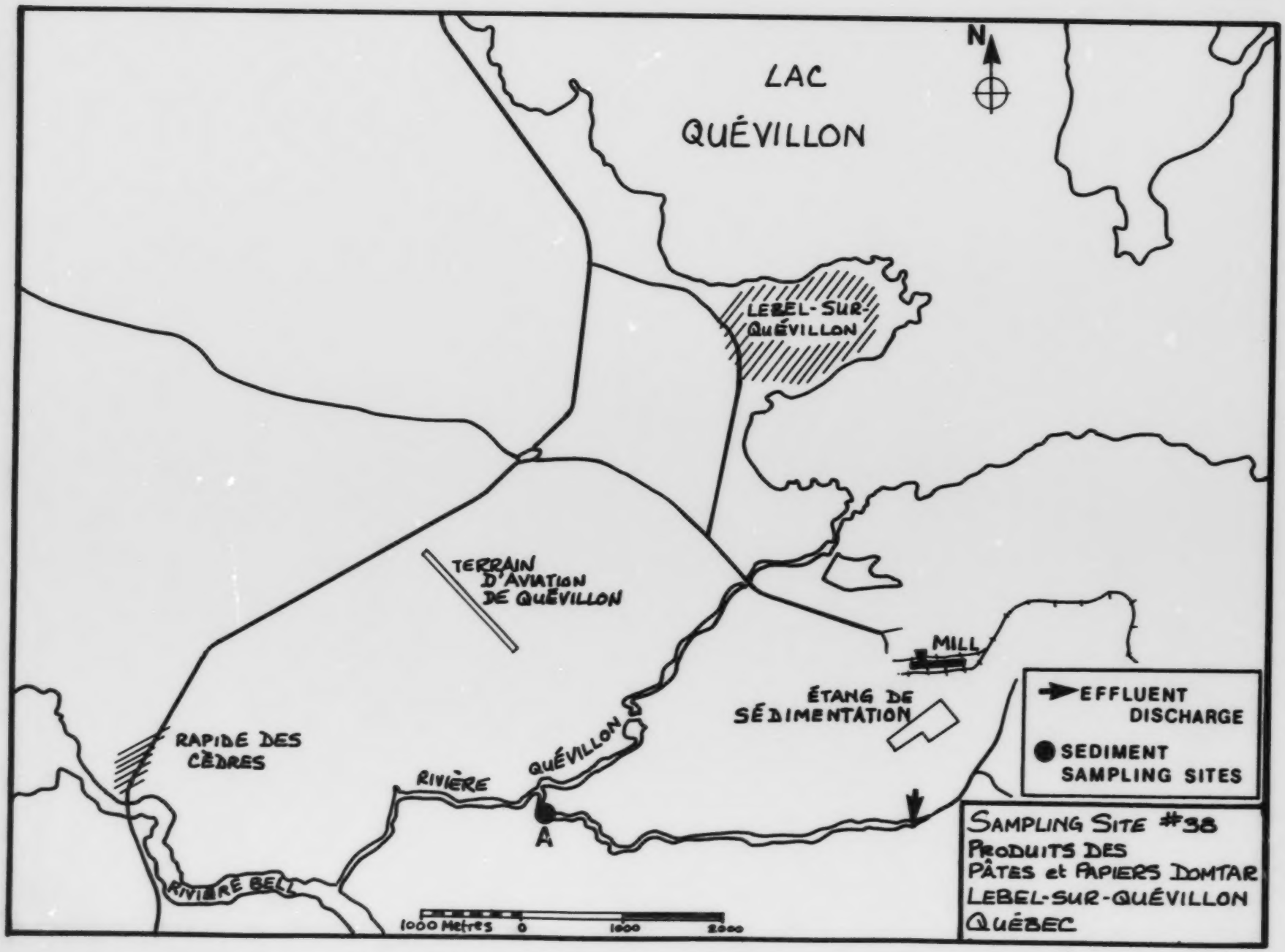

≃ 500 m. BETWEEN B AND C
≃ 100 m. BETWEEN EFFLUENT AND B
A APPROX 500 m UPSTREAM FROM THE BRIDGE
N
61
CLEAN WATER SEWER
TURNING BASIN
C
A
KAMINISTIQUIA RIVER
MILL
B
MAIN EFFLUENT
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #33
CP FOREST PRODUCTS LTD
THUNDER BAY
ONTARIO.

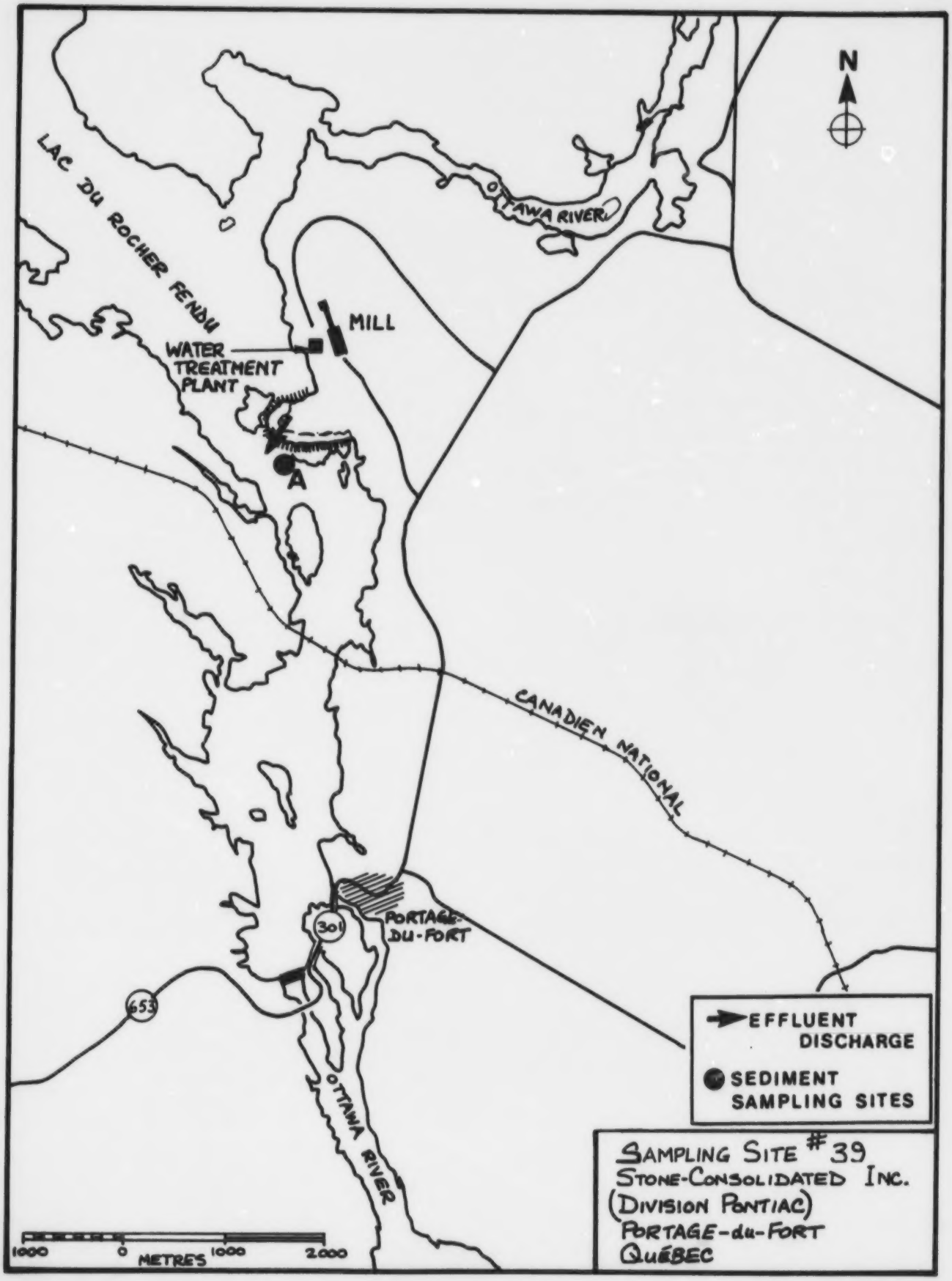

N
C
B
EFFLUENT
LAGOON
DAM
PULP MILL
≃ 30-50m BETWEEN A AND THE EFFLUENT
≃ 250m BETWEEN B AND C
A TAKEN APPROX 200m UPSTREAM OF THE BRIDGE
HWY 17
A
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #34
MALETTE KRAFT
PULP AND PAPER
SMOOTH ROCK FALLS
ONTARIO

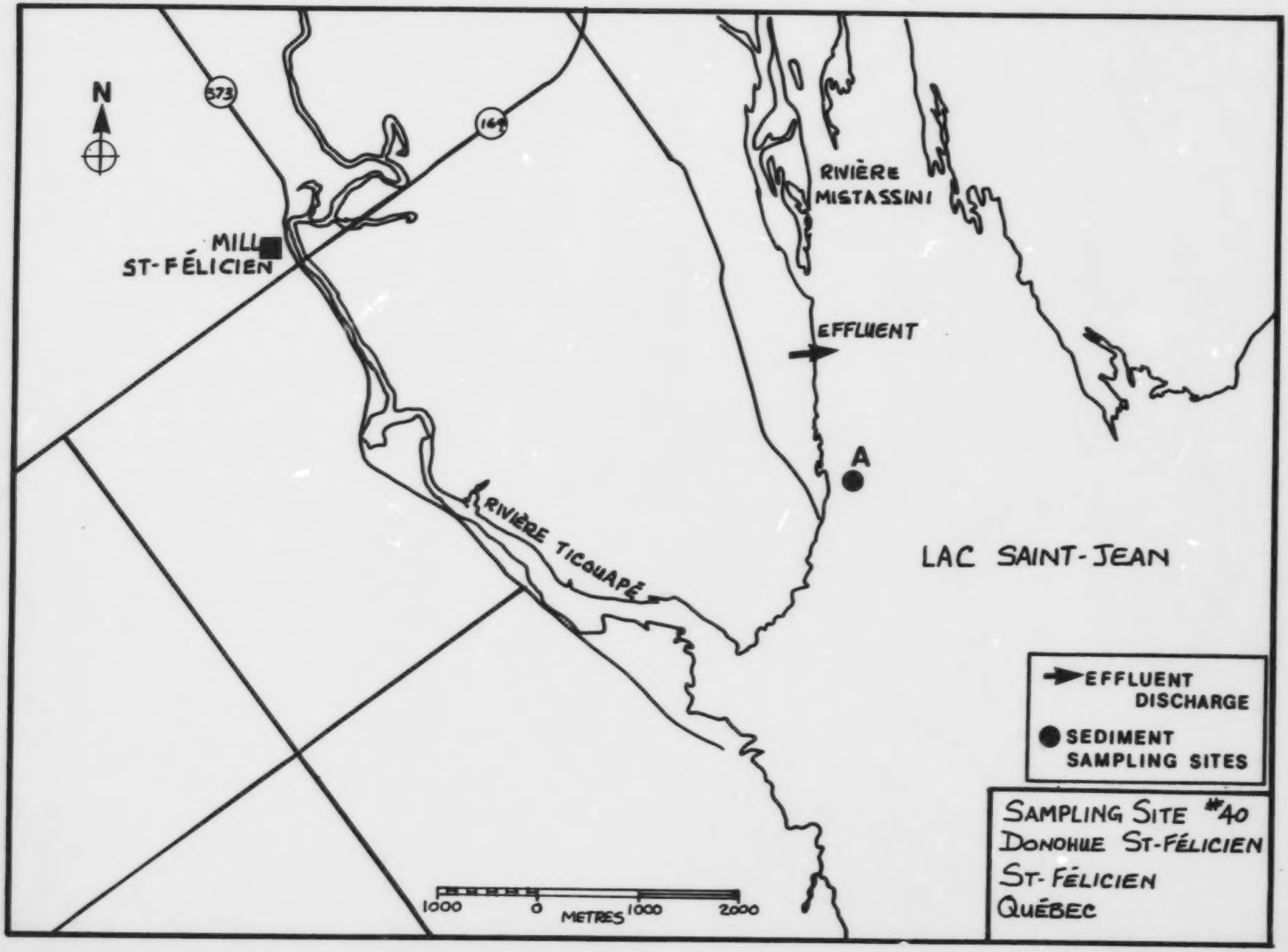

LAC TÉMISCAMINGUE
46
LAC AUX BROCHETS
101
N
TÉMISCAMING
EFFLUENT
MILL
BARRAGE DU LAC TÉMISCAMINGUE
A
OTTAWA
C.P.R.
RIVER
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
1000 0 1000 2000 METRES
SAMPLING SITE #35
TEMBEC INC
TÉMISCAMING
QUÉBEC

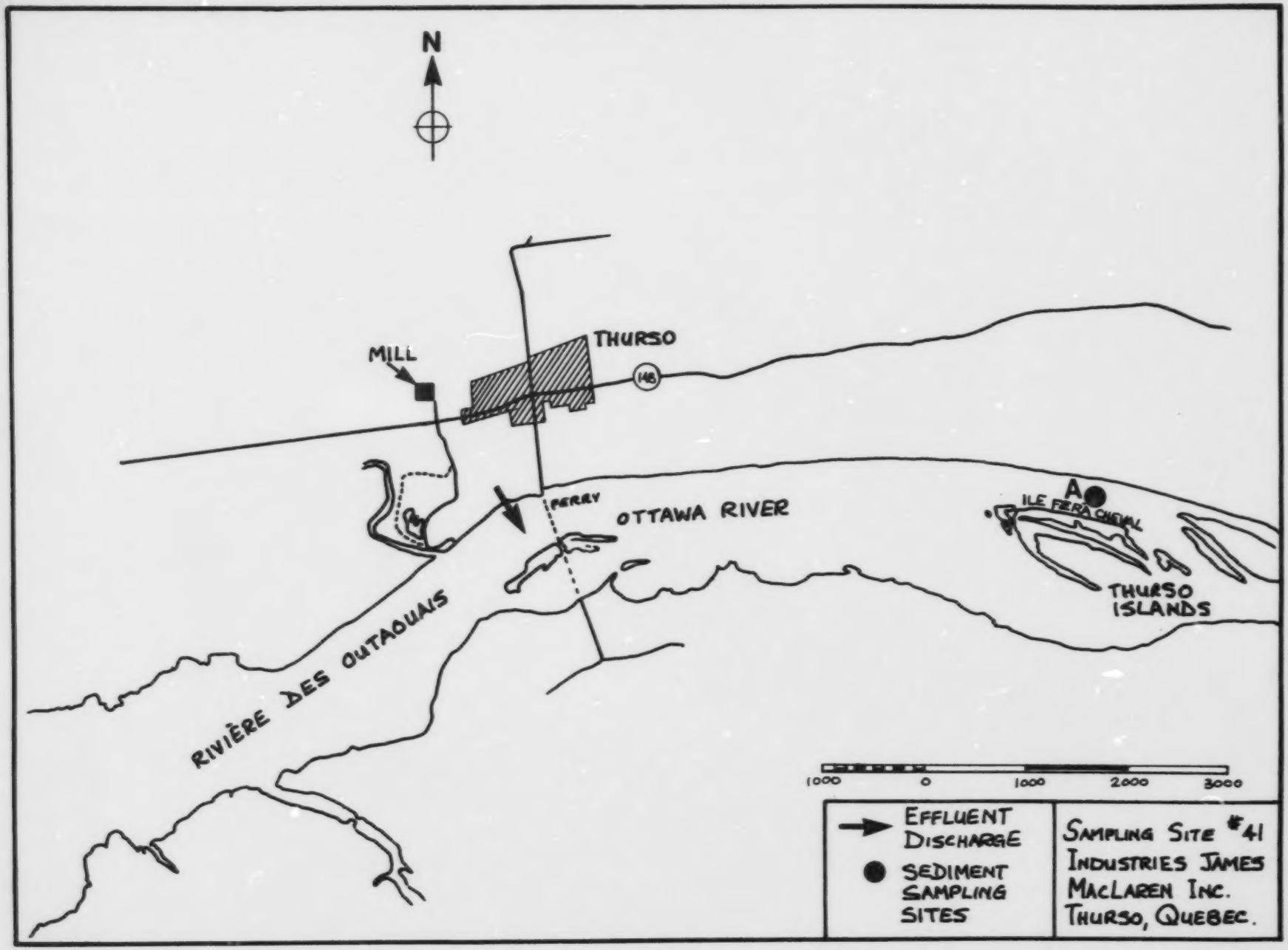

N
RIVIÈRE SHIPSHAW
POWER HOUSE
A
SAGUENAY RIVER
EFFLUENT
MILL
16
JONQUIÈRE
ARVIDA
16A
CHICOUTIMI
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #36
CASCADES INC.
JONQUIÈRE
QUÉBEC
0
1
2
3
KMS

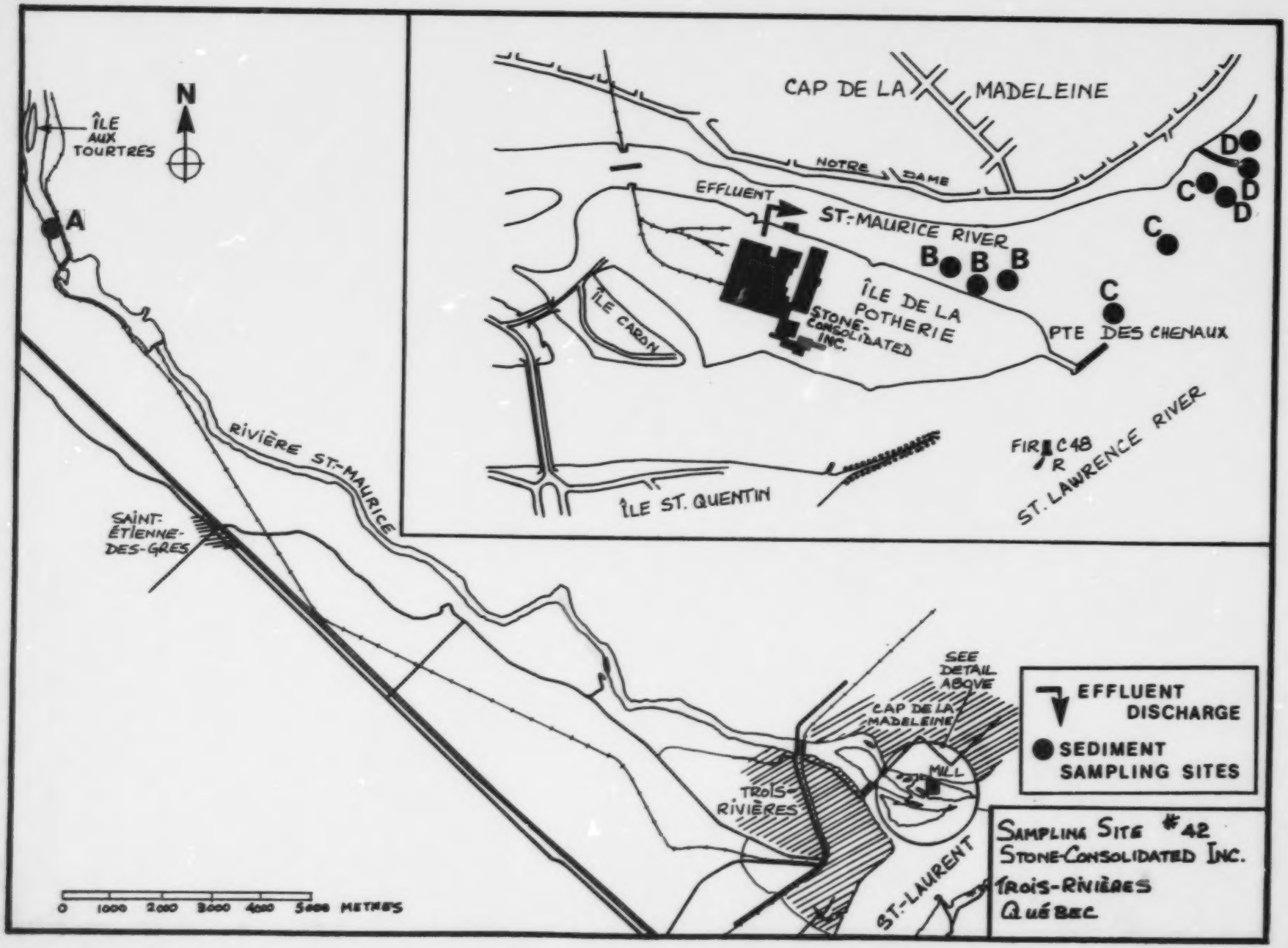

N
ST. MAURICE RIVER
DAM
MILL
LA TUQUE
ILE AU GOELAND
A
C.N.R.
19
1000 0 1000 2000 3000
METRES
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #37
LES PRODUITS FORESTIERS
CANADIEN PACIFIQUE LTÉE
LA TUQUE
QUEBEC

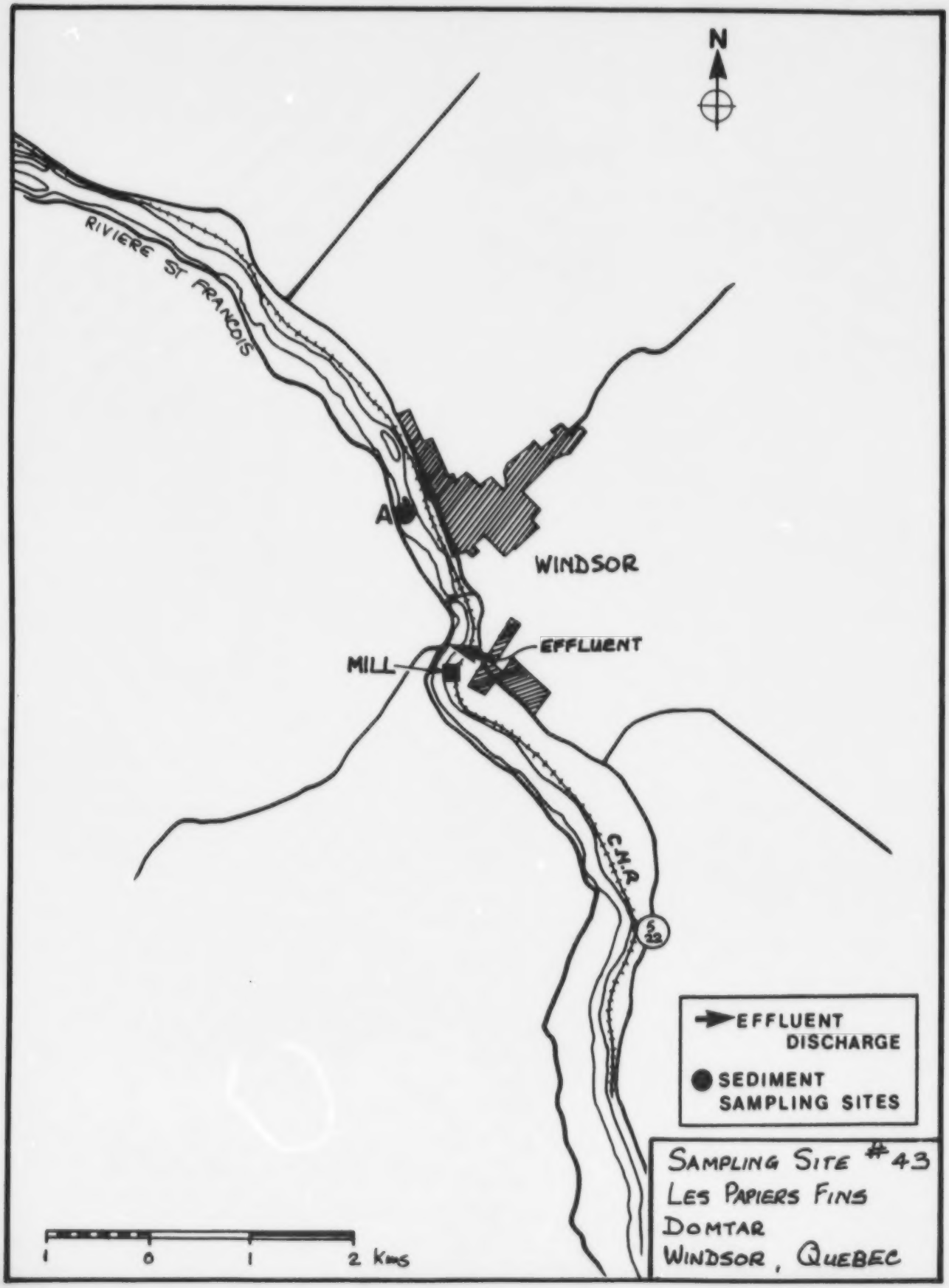

LAC
QUÉVILLON
N
LEBEL-SUR-QUÉVILLON
TERRAIN D'AVIATION DE QUÉVILLON
MILL
ÉTANG DE SÉDIMENTATION
RAPIDE DES CÈDRES
RIVIÈRE QUÉVILLON
A
RIVIÈRE BELL
1000 Metres 0 1000 2000
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #38
PRODUITS DES PÂTES et PAPIERS DOMTAR
LEBEL-SUR-QUÉVILLON
QUÉBEC

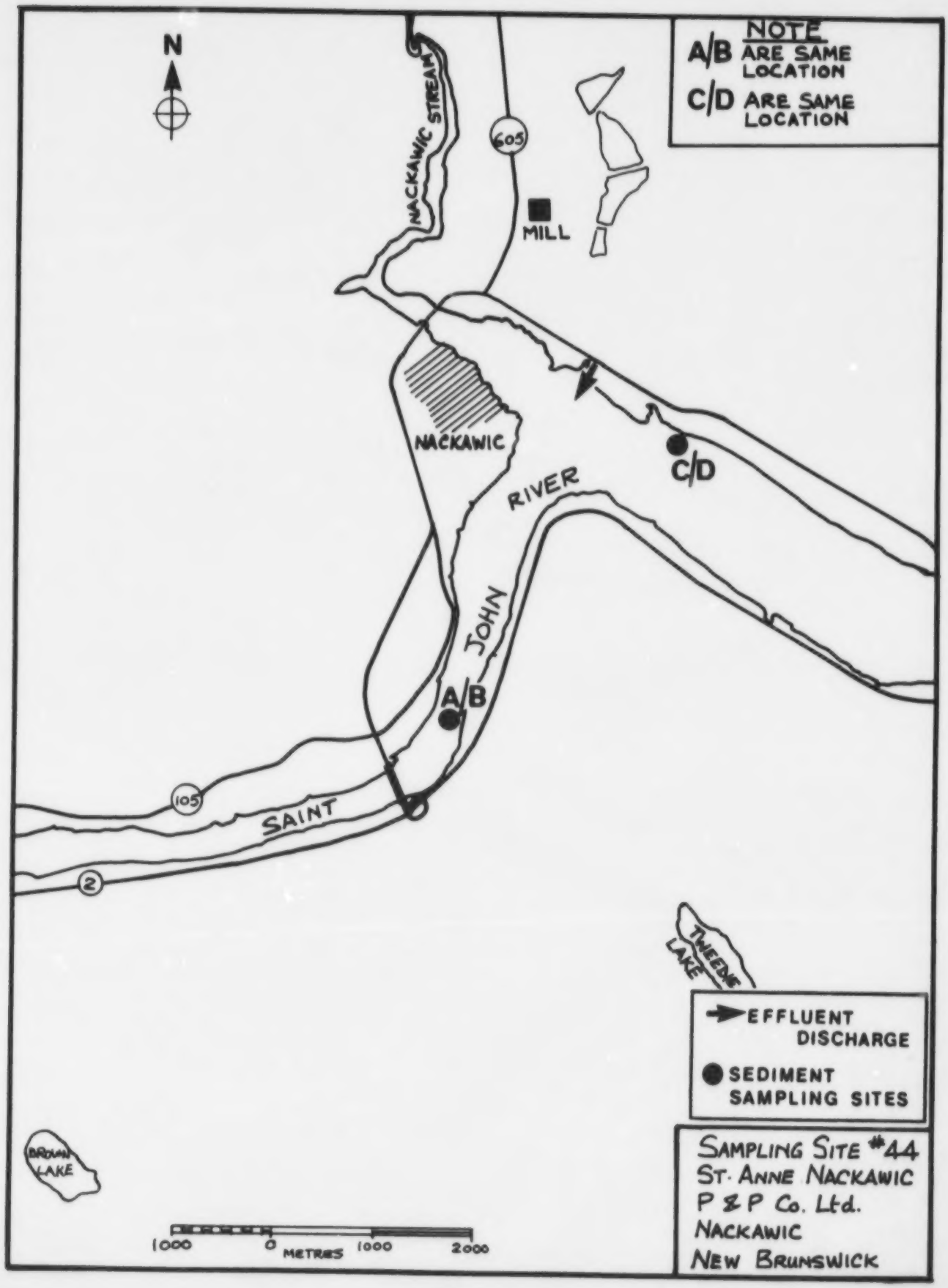

N
LAC DU ROCHER FENDU
OTTAWA RIVER
MILL
WATER TREATMENT PLANT
A
CANADIEN NATIONAL
PORTAGE-DU-FORT
301
653
OTTAWA RIVER
1000 0 METRES 1000 2000
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE # 39
STONE-CONSOLIDATED INC.
(DIVISION PONTIAC)
PORTAGE-du-FORT
QUÉBEC

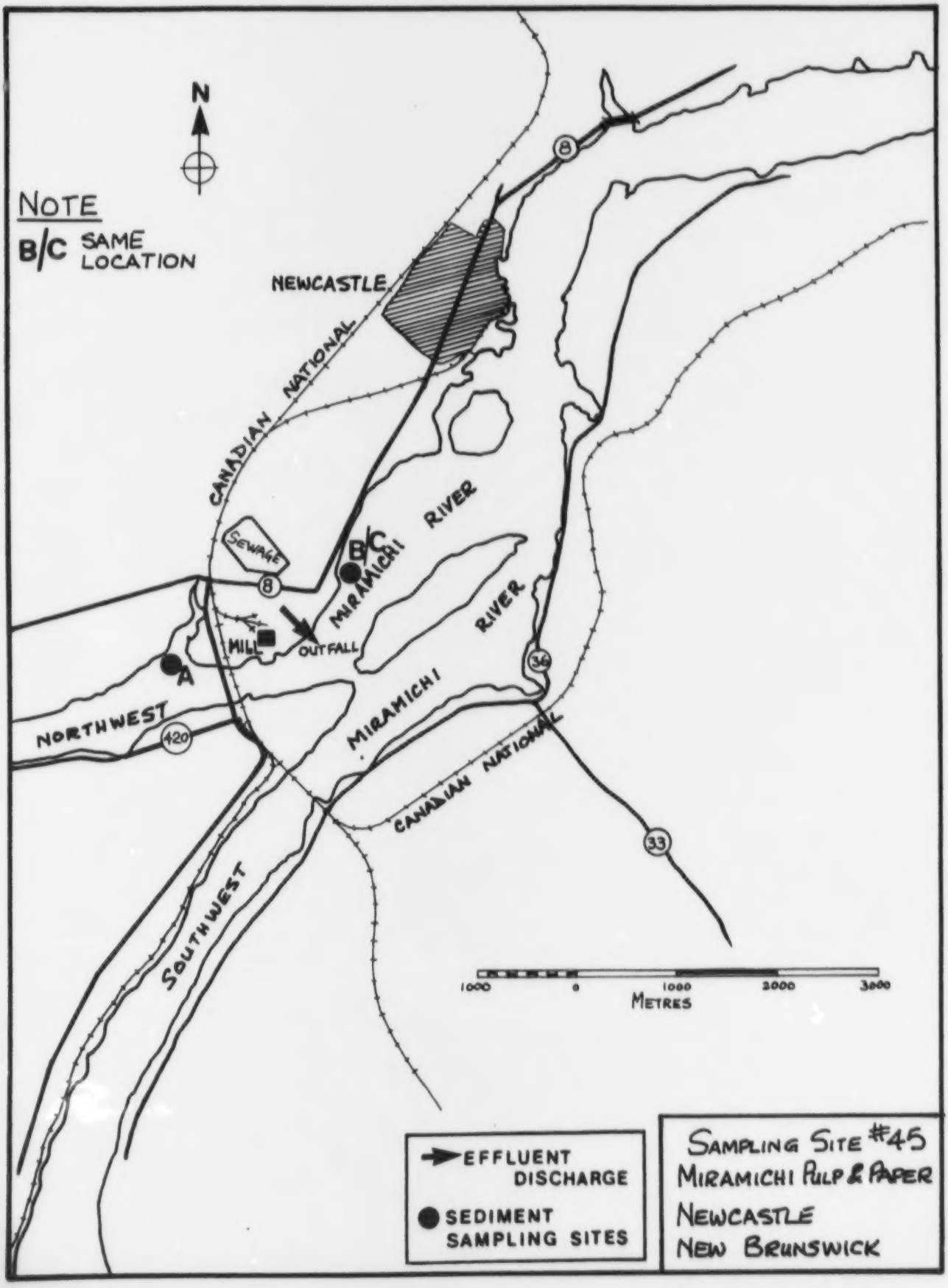

N
373
169
MILL
ST-FÉLICIEN
RIVIÈRE
MISTASSINI
EFFLUENT
A
RIVIÈRE TICOUAPÉ
LAC SAINT-JEAN
EFFLUENT
DISCHARGE
SEDIMENT
SAMPLING SITES
SAMPLING SITE #40
DONOHUE ST-FÉLICIEN
ST-FÉLICIEN
QUÉBEC
1000
0
METRES
1000
2000

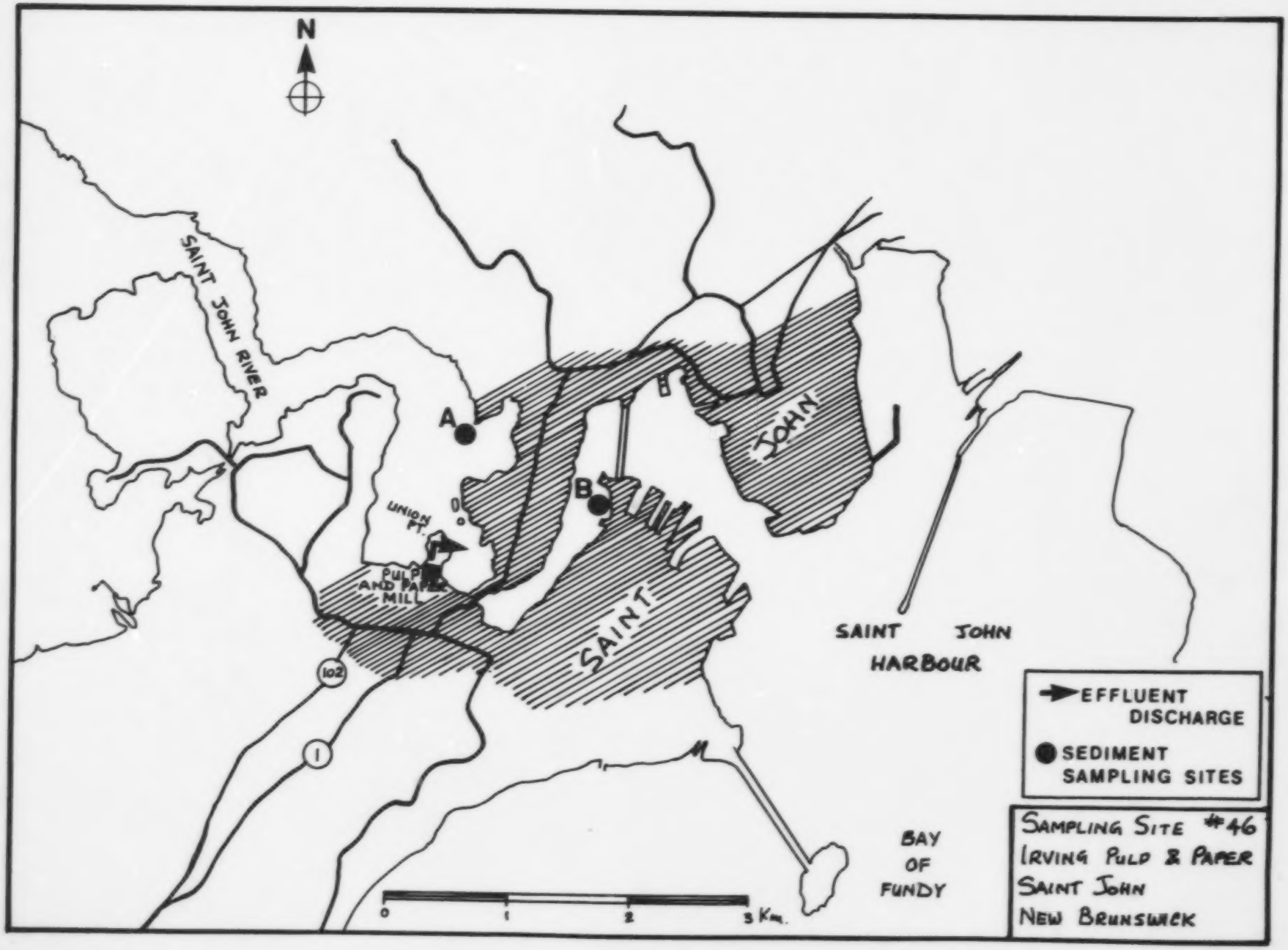

N
MILL
THURSO
148
FERRY
OTTAWA RIVER
A
ILE PERA CHEVAL
THURSO ISLANDS
RIVIÈRE DES OUTAOUAIS
1000
0
1000
2000
3000
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #41
INDUSTRIES JAMES MACLAREN INC.
THURSO, QUEBEC.


N
ÎLE AUX TOURTRES
A
RIVIÈRE ST-MAURICE
SAINT-ÉTIENNE-DES-GRES
0 1000 2000 3000 4000 5000 METRES
CAP DE LA MADELEINE
NOTRE DAME
EFFLUENT
ST.-MAURICE RIVER
B B B
C
C
D D D
ÎLE CARON
ÎLE DE LA POTHERIE
STONE-CONSOLIDATED INC.
PTE DES CHENAUX
ÎLE ST. QUENTIN
FIG. C48
ST. LAWRENCE RIVER
SEE DETAIL ABOVE
CAP DE LA MADELEINE
MILL
TROIS-RIVIÈRES
ST.-LAURENT
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #42
STONE-CONSOLIDATED INC.
TROIS-RIVIÈRES
QUÉBEC


N
RIVIERE ST FRANCOIS
A
WINDSOR
EFFLUENT
MILL
C.N.R
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #43
LES PAPIERS FINS
DOMTAR
WINDSOR, QUEBEC
1 0 1 2 Kms


N
NOTE
A/B ARE SAME LOCATION
C/D ARE SAME LOCATION
NACKAWIC STREAM
605
MILL
NACKAWIC
RIVER
JOHN
SAINT
105
2
A/B
C/D
TWEEDIE LAKE
BROWN LAKE
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
1000
0
METRES
1000
2000
SAMPLING SITE #44
ST. ANNE NACKAWIC
P & P Co. Ltd.
NACKAWIC
NEW BRUNSWICK


N
NOTE
B/C SAME LOCATION
NEWCASTLE
CANADIAN NATIONAL
8
SEWAGE
B/C
MIRAMICHI RIVER
MILL
OUTFALL
A
NORTHWEST
420
MIRAMICHI RIVER
34
CANADIAN NATIONAL
33
SOUTHWEST
1000 0 1000 2000 3000
METRES
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #45
MIRAMICHI PULP & PAPER
NEWCASTLE
NEW BRUNSWICK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SAINT JOHN RIVER
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PULP AND PAPER MILL
SAINT JOHN
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102
1
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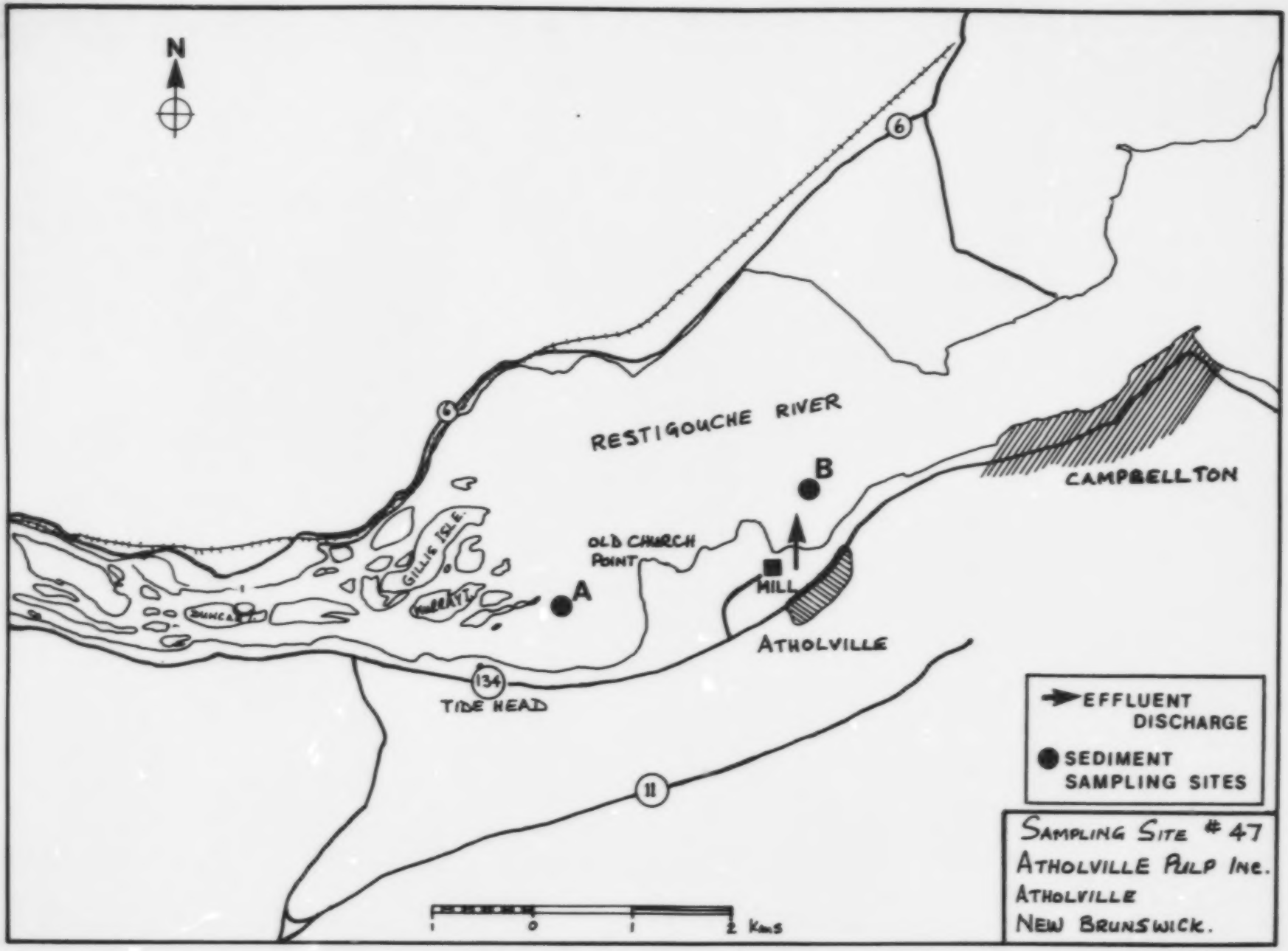
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RESTIGOUCHE RIVER
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OLD CHURCH POINT
GILLIS ISLE
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MILL
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TIDE HEAD
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ATHOLVILLE
NEW BRUNSWICK.
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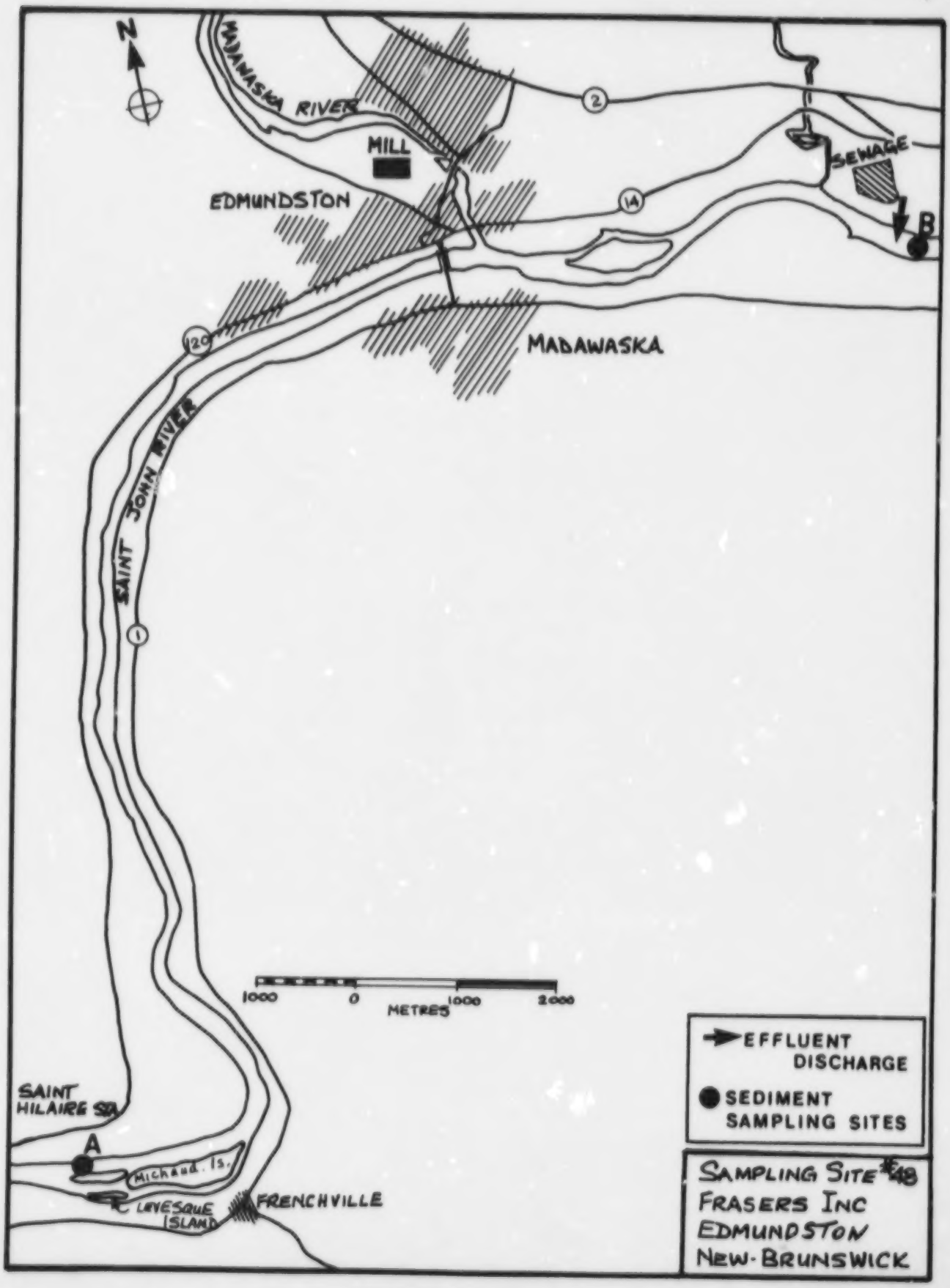
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FRASERS INC
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SAINT HILAIRE ST.
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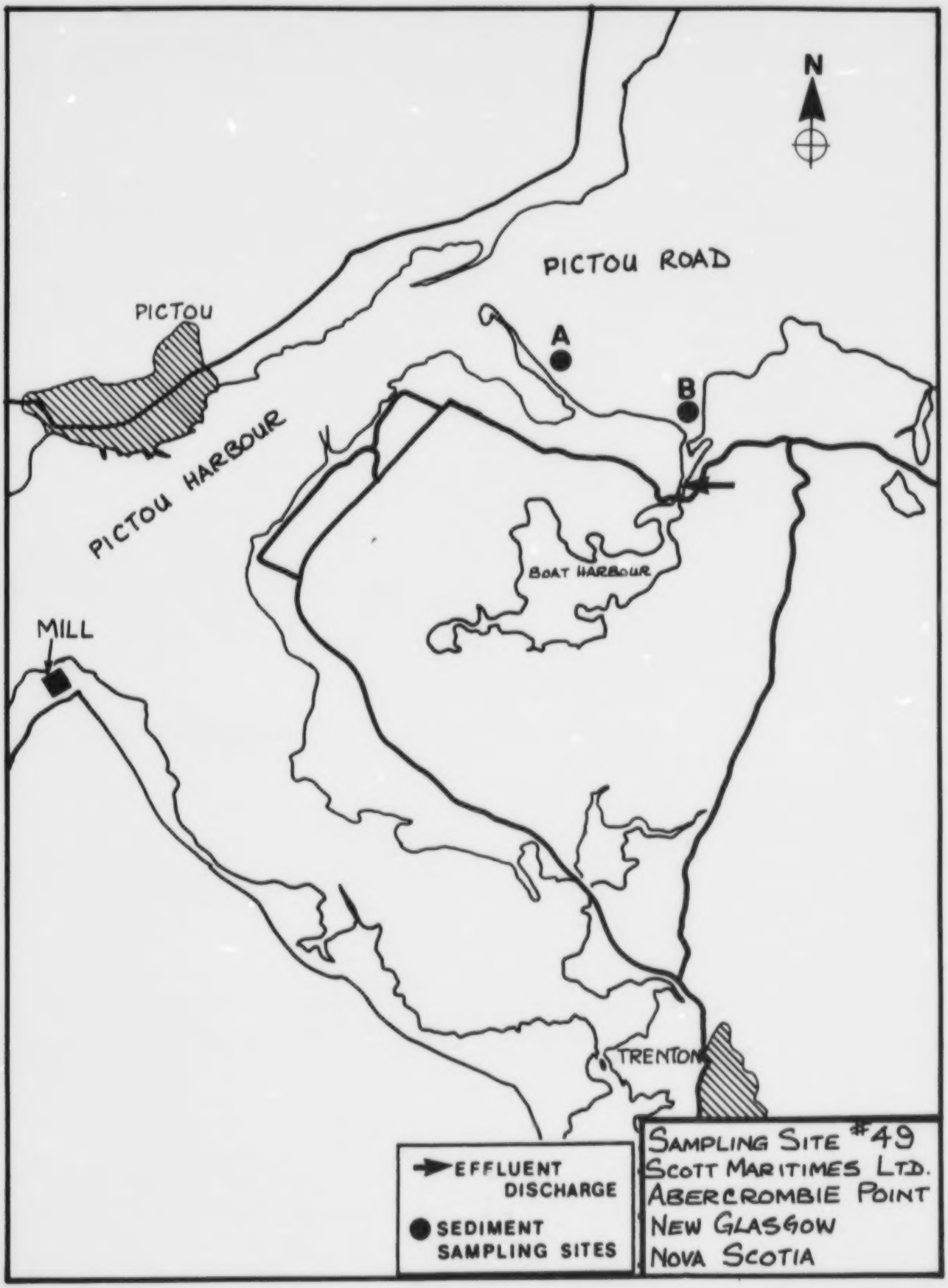
Michaud Is.
LEVESQUE ISLAND
FRENCHVILLE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BOAT HARBOUR
MILL
TRENTON
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITES
SAMPLING SITE #49
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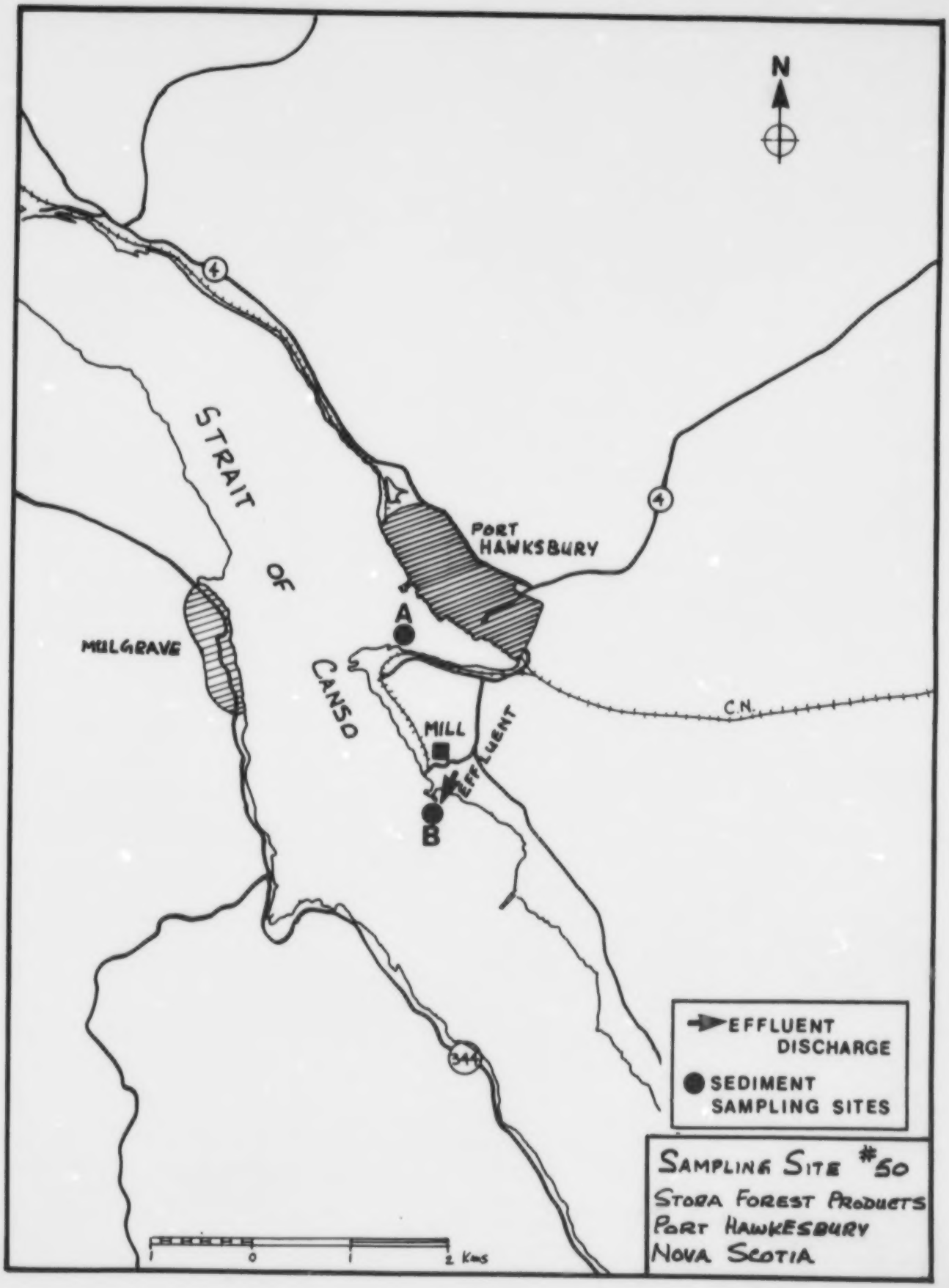
ABERCROMBIE POINT
NEW GLASGOW
NOVA SCOTIA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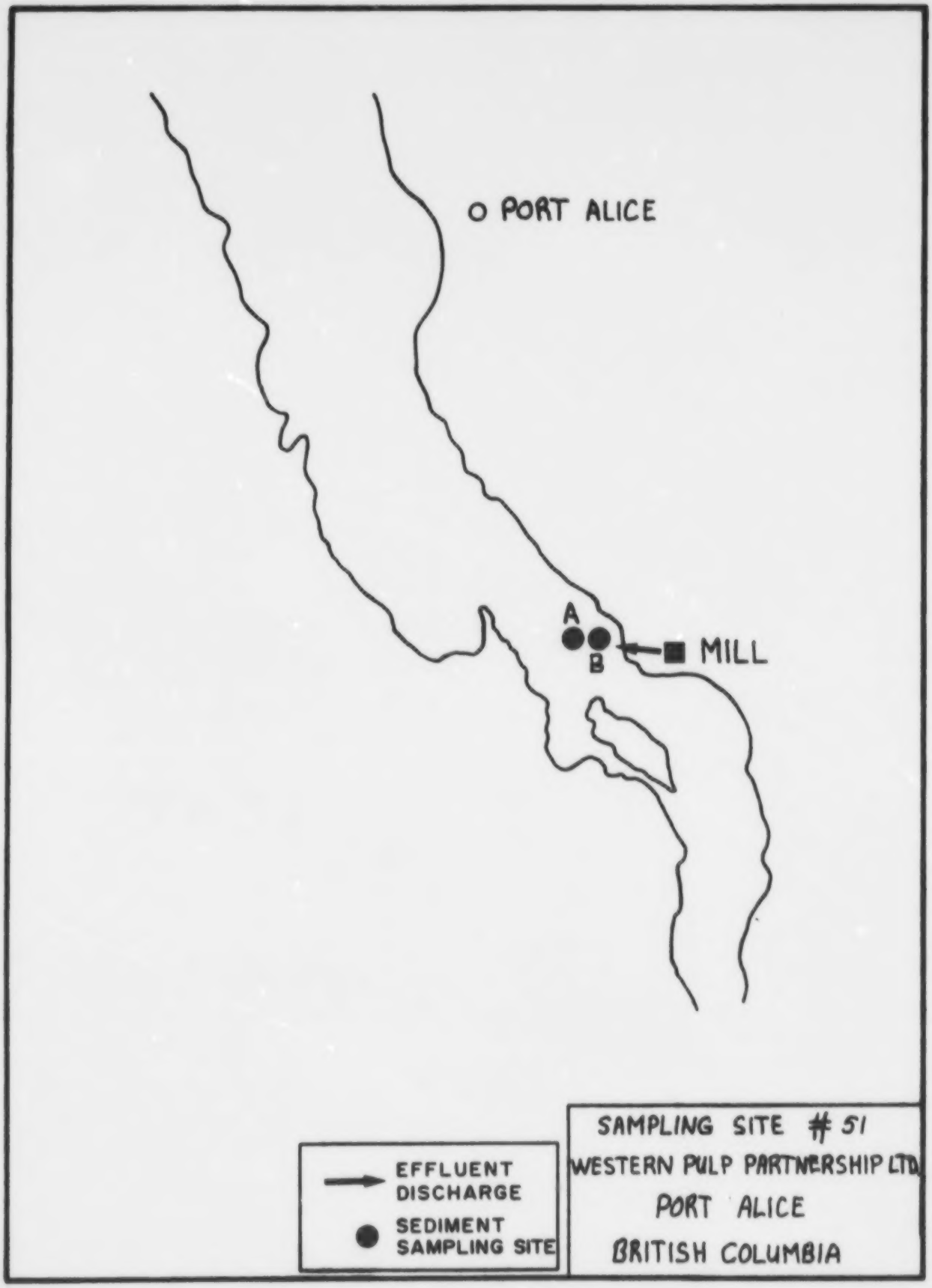
PORT ALICE
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MILL
EFFLUENT DISCHARGE
SEDIMENT SAMPLING SITE
SAMPLING SITE # 51
WESTERN PULP PARTNERSHIP LTD.
PORT ALICE
BRITISH COLUMBIA

APPENDIX B
PROTOCOL FOR SEDIMENT SAMPLING

SAMPLING OF SEDIMENT FOR DIOXINS

There are several basic factors which affect the quality of environmental data. They are: sample collection; sample preservation, sample analysis and data recording. Improper action in any one of these areas may result in poor data which may affect the conclusions and recommendations of the study. When collecting an environmental sample, the following should be considered:

(1) equipment and supplies;
(2) equipment cleaning procedure;
(3) site selection, and
(4) sample collection method.

(1) EQUIPMENT AND SUPPLIES

When collecting a sediment sample for dioxin analysis the following equipment and supplies are recommended:

(a) Eckman dredge;
(b) Ponar sampler;
(c) Stainless steel steam table tray;
(d) Stainless steel bucket;
(e) Stainless steel soup ladle;
(f) Large stainless steel serving spoon;
(g) Teflon jars (4 oz.);
(h) Teflon wash bottles (3);
(i) Aluminum foil;
(j) Pesticide grade acetone, hexane and methylene chloride - then hexane again;
(k) Coleman cooler containing dry ice.

(2) EQUIPMENT CLEANING PROCEDURE

Due to the high cost of analyzing for dioxins (approximately $1,000 per sample), it is recommended that the following cleaning procedure be used for all sampling equipment;

(a) Wash with tap water and soapy water;
(b) Rinse well with tap water and deionized water;
(c) Rinse with pesticide grade acetone, hexane and methylene chlorine respectively; then hexane;
(d) Air dry and wherever possible, heat to 350°C overnight;
(e) Wrap all cleaned sampling equipment with cleaned and heat-treated aluminum foil until required;
(f) Before each sampling, rinse all equipment with acetone, hexane, methylene chloride and water from the sampling site.

On the surface, this tedious and expansive cleaning procedure seems to be an over-kill. However, it is better to be safe and avoid the question of contamination later.

(3) SELECTION OF SAMPLING LOCATION

Usually, the program objectives give a general indication of the location for sampling. Since sediment quality (e.g., particle size) varies from place to place in a river system, locations appropriate to the information needs of a particular program must be selected. The selection of the sampling location must consider the following: homogeneity, general characteristics, quality degradation, convenience, accessibility and practicability.

Due to the high cost of analysis, restrictions must be put on the number of samples that can be submitted for analysis. Keeping the objective of the program in mind, three sampling sites should be selected in the effluent plume where fine sediment (clay fraction) is available. Similarly, three sites well above the influence of the mill should be selected for background stations. In selecting these background sites one should always be concerned with wood protection and wood preservation facilities. Fine sediments in a dynamic river system are difficult to find. Therefore, the sampling location is wherever one can find the fine sediment within the area of interest.

(4) SAMPLE COLLECTING METHOD

The following method for collecting bed sediments is recommended:

(a) Take sample with suitable sampler (Eckman dredge, Ponar sampler, soup ladle, etc.);
(b) Put sample in steam table tray;
(c) Take top 1 cm with serving spoon and put into stainless steel bucket;
(d) Composite three grab samples from each site as well as samples from all three sites and mix well;
(e) Put sample into teflon jar with spoon;
(f) Put sample in Coleman cooler containing dry ice.

The success of the program depends on all basic factors that influence the quality of the data. The quality of the data produced in the laboratory is as good as the sample submitted. Therefore, it is important to keep the sample frozen at all times during transmit to the laboratory.

APPENDIX C
ANALYTICAL METHODS FOR SEDIMENTS

APPENDIX C-1. Analytical Method for Particle Size Distribution.

APPENDIX C-2. Analytical Method for Organic Carbon Analysis.

APPENDIX C-1

ANALYTICAL METHOD FOR PARTICLE SIZE DISTRIBUTION

Subsamples of the sediments were forwarded to two laboratories for analysis of particle size distribution: Soilcon Laboratories Ltd. and the Water Resources Branch Laboratories (Environment Canada) in Regina and Vancouver. Methods used for particle size determination are described below. Appendix V lists the analytical laboratory which performed analysis for each sample.

1) SOILCON LABORATORIES

A total of 14 samples was analysed by Soilcon for particle size determination. The methods used were hydrometer and sieve analysis. Pipette method was used for samples 22B and 22BB. The hydrometer or pipette method is used to measure the proportion of particles equal or less than 53 µm. The proportion of particles greater than 53 µm were measured by either wet or dry sieving. All samples were treated with hydrogen peroxide and hydrochloric acid to destroy organic matter and then analyzed by wet sieve and hydrometer following procedures outlined in McKeague (1978).

2) WATER RESOURCE BRANCH LABORATORIES

Particle size distributions were determined by hydrometer, bottom withdrawal or sieve analysis methods using procedures described in Environment Canada (1988). The method chosen depended on the sample composition. Removal of organics was carried out for only a select number of samples. The presence of organics in the rest of the samples was not significant and did not appear to affect the results.

REFERENCES

McKeague, J.A. (Ed.). 1978. Manual on Soil Sampling and Methods of Analysis. 2nd ed. Subcommittee on Methods of Analysis of the Canada Soil Survey Committee, Canadian Society of Soil Science, Ottawa.

Environment Canada. 1988. Laboratory Procedures for Sediment Analysis, 2nd Edition, Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Ottawa, Canada, IWD-HQ-WRB-SS-84-5, 78 p.

APPENDIX C-2

ANALYTICAL FOR ORGANIC CARBON ANALYSIS

Subsamples of the sediments were forwarded for organic carbon content analysis to Soilcon Laboratories Ltd., XRal Environmental and the National Water Quality Laboratory (Burlington). Methods for organic carbon content are described below. Appendix V lists the analytical laboratory which performed analysis for each sample.

1) XRAL ENVIRONMENTAL INC.

A total of 42 samples was analyzed by XRal Environmental laboratory. Results for total carbon (included inorganic carbon as well, instead of total organic carbon as requested) were provided for four samples: 26D, 26E, 32A, 32B.

Operation Principles of Coulometer - By Coulometrics Inc.

The coulometric cell is filled with partially aqueous solution containing monoethanolamine and a colorimetric indicator. When a gas is passed through the solution, CO2 is quantitatively absorbed forming a strong titratable acid with monoethanolamine, causing the indicator color to fade. The coulometer electrically generates a base to return the color to the starting point. The total amount of current required for the titration is calibrated as micrograms of carbon or carbon dioxide. Sample size used varies from 0.02 to 0.10 gram.

Total Carbon

Samples are combusted in coulometric tube furnace at 1000°C with oxygen to convert organic and inorganic forms of carbon to CO2. The sample combustion gases are swept through the barium chromate and scrubbers to ensure complete oxidation of carbon to CO2 and removal of other interference gases, such as SO3, NO2 and C12. The carbon dioxide is then measured with the coulometer. Detection limit is 0.01%.

Organic Carbon

Samples are placed in the coulometer reaction cell and treated with sulphuric acid to release any CO2 present. CO2 can be determined at this point if it is required. When all CO2 has been expelled, any organic carbon present is converted to CO2 by the addition of potassium dichromate (which forms chromic acid), CO2 thus formed is titrated automatically. Detection limit is 0.05%.

2) SOILCON LTD.

A total of 15 samples were analyzed by Soilcon Laboratories. Total carbon is determined using a Leco Analyzer #132 (high temperature induction furnace) (Nelson and Sommers 1982). The organic carbon is determined by analyzing the soil for both total carbon and inorganic carbon; the organic carbon is calculated by subtracting the inorganic carbon from the total carbon present. The samples are tested for the presence of carbonate carbon by adding 4H HCL dropwise to a vetted soil sample, and observing any effervescence. If present, the carbonate C is measured using gravimetric method (McKeague 1978).

The tabulated carbon values are total carbon values. The HCL test indicated the presence of carbonates (inorganic carbon) in three samples: 22B, 22BB, 23A. During the particle size analysis, these samples were pretreated for the removal of carbonates, in addition to the routine removal of organic matter. Unfortunately, we did not have sufficient sample to run the gravimetric method for determining carbonate carbon. The total carbon values for these three samples therefore include both organic carbon and inorganic carbon. For the remaining samples, the total carbon value can be interpreted as organic carbon, because carbonate carbon was not indicated by the HCL test.

3) NATIONAL WATER QUALITY LABORATORY

Particulate Organic Carbon Determinations

A total of 87 samples were analyzed by the NWQL. The method used was identical to NAQUADAT 06903 (Environment Canada 1979; 1988) for the determination of particulate organic carbon.

Sediment samples were dried at 100°C overnight and then pulverized in a shatter box (Spex Ind. Inc.). Inorganic carbon was removed by suspending the pulverized sediment was filtered and washed with deionized water. Then the sediment was transferred to a Petri dish and dried in a heated vacuum dessicator at 67-80°C overnight. Approximately 1 mg of dried residue was weighed and pressed into a capsule with a hand press. The resultant capsule was analyzed using a Model 240XA Elemental Analyzer. The method was identical to NAQUADAT 06903 (Environment Canada 1979; 1988b) except that the dried, acid washed sediment was pressed into a capsule and no catalyst was added.

REFERENCES

Nelson, D.W. and L.E. Sommers. 1982. Total Carbon, Organic Carbon and Organic Matter. In: Methods of Soil Analysis, Part 2- Chemical and Microbiological Properties, A.L. Page (ed.). 2nd ed. Agronomy No. 9. American Society of Agronomy, Inc., Wisconsin. pp. 539-580.

McKeague, J.A. (Ed.). 1978. Manual on Soil Sampling and Methods of Analysis. 2nd ed. Subcommittee on Methods of Analysis of the Canada Soil Survey Committee, Canadian Society of Soil Science, Ottawa.

Environment Canada. 1979. Analytical Methods Manual, Water Quality Branch, Inland Waters Directorate, Ottawa, Canada.

Environment Canada. 1988. NAQUADAT, Dictionary of Parameter Codes, Data Systems Section, Water Quality Branch, Inland Waters Directorate, Ottawa, Canada.

APPENDIX D
QUALITY ASSURANCE/QUALITY CONTROL

TABLE D-1. Surrogate Standard Solutions Used by the Laboratories. Constituents, Concentration and Amount of Spike.

TABLE D-2. Recoveries of Surrogate Standards, Mean, Range, Standard Deviation and Coefficient of Variation.

TABLE D-3A. Intralaboratory Quality Control: Results on Duplicate Sediment Samples - Dioxin.

TABLE D-3B. Intralaboratory Quality Control: Results on Duplicate Sediment Samples - Furan.

TABLE D-4A. Interlaboratory Quality Control: Dioxin Results on Reference Material Samples.

TABLE D-4B. Interlaboratory Quality Control: Furan Results on Reference Material Samples.

TABLE D-5 Interlaboratory Quality Control: Dioxin and Furan Results on Replicate of Wet Sediment Sample Split in the Field.

APPENDIX D

QUALITY ASSURANCE/QUALITY CONTROL

1. QUALITY ASSURANCE/QUALITY CONTROL PROCEDURE

Quality Assurance (QA)/Quality Control (QC) activities were implemented to provide essential information regarding internal laboratory practices and performance, reproducibility, bias and comparability of the analytical data. QA/QC activities were a principal consideration of this study and will be reflected in the interpretation of the results.

A detailed QA protocol, developed by the DQAC (Dioxin Quality Assurance Committee, Environment Canada) and specifically intended for the CPPA (Canadian Pulp and Paper Association) Monitoring Program (DQAC, 1989), was adopted within the sediment program.

The quality control activities consisted firstly of instructing the sediment sample collectors about sampling procedure, sample handling, transportation, preservation and storage. Site selection criteria and detailed field activities protocols were provided as described in Section 2.0. Contamination of sample containers was minimized by the use of cleaning techniques; however, "bottle quality control" was not carried out.

1.1 Internal Laboratory QC Procedures

Intralaboratory QC procedures were conducted routinely by each of the participating laboratories and are outlined in the laboratory reports. Major elements and common points of these intralaboratory QC procedures are summarized below:

- All glassware was cleaned and rinsed with appropriate solvents before use and tested for analyte detection. A complete description of the procedure is given by Seakem, National Water Quality Laboratory (NWQL) and River Road Environmental Technology Center (RRETC) laboratories.

- The possibility of contamination due to laboratory processing operations was monitored by method blank samples prepared by each laboratory. At NWQL, RRETC and Wellington laboratories, a method blank sample was run for each set of 10-12 samples. The Seakem laboratory ran procedural blanks for 10% of the samples in every batch. Frequency of blank sample analysis was not specified in the Eco Logic and Wellington laboratory procedures.

- Overall method performance was assessed regularly using method spikes (blank samples spiked with native and surrogate analytes). The NWQL processed one method spike with each batch of 10 samples. The QA/QC procedure provided by Wellington laboratory indicated the use of one spiked sample for every set of 10 samples.

- Performance standards (isotopically-labelled $^{13}C_{12}$-1,2,3,4-T_4CDD) were added to each sample extract prior to GC/MS analysis to assess the success of the injection and instrument stability.

- A mixture of surrogate isotopically labelled (C_{13}) standards (Table D-1) was added to each sediment sample prior to extraction to demonstrate overall recoveries through all phases of the extraction, clean-up and quantitation procedures and to assess the degree of analyte loss. Samples showing low recoveries were reanalyzed until the specified acceptable recovery levels were achieved.

- The GC/MS was periodically calibrated using native analyte standard solutions.

- Positive identification of CDDs and CDFs was based on definition of retention time window, ratio of peaks and peak responses (signal to background noise levels).

1.2 Other QC Activities

In addition to intralaboratory QC procedures operated on a continuous basis, other specific quality control activities were carried out to address the following data quality aspects:

(1) **Reproducibility** of results
(2) **Bias** of analyses
(3) **Comparability** of interlaboratory results

The national sediment survey was carried out from 1987 to 1990. Five laboratories were involved at different times to carry out sediment analysis. The RRETC and NWQL laboratories conducted analyses at the beginning of the survey (mainly in 1987 and 1988) while the three commercial laboratories were involved in February and March 1989. A final set of 20 samples from Ontario and Quebec were analyzed by the NWQL in March 1990. A Quality Control study was designed to assess the performance of the three commercial laboratories but did not address whether previous results from RRETC and NWQL were reproducible and comparable. This accounts for the absence of RRETC and NWQL laboratories in certain parts of the Quality Control study described below.

TABLE D-1. Surrogate Standard Solutions Used by the Laboratories. Constituents, Concentration and Amount of Spike.

Laboratory	Surrogate	Concentration (pg/µL)	Total added (pg)	Quantity added (µL)
Wellington	C13-2378-T_4CDD	100	5000	50
	C13-12378-P_5CDD	100	5000	
	C13-123678-H_6CDD	100	5000	
	C13-1234678-H_7CDD	100	5000	
	C13-O_8CDD	100	5000	
Seakem	C13-2378-T_4CDD	100	2000	20
	C13-2378-T_4CDF	100	2000	
	C13-12378-P_5CDD	100	2000	
	C13-123678-H_6CDD	200	4000	
	C13-1234678-H_7CDD	200	4000	
	C13-O_8CDD	300	6000	
Eco Logic	C13-2378-T_4CDD	100	2000	20
	C13-12378-P_5CDD	100	2000	
	C13-123678-H_6CDD	100	2000	
	C13-1234678-H_7CDD	100	2000	
	C13-O_8CDD	100	2000	
RRETC	C13-2378-T_4CDD	20	2000	100
	C13-2378-T_4CDF	20	2000	
	C13-12378-P_5CDD	20	2000	
	C13-123678-H_6CDD	40	4000	
	C13-1234678-H_7CDD	40	4000	
	C13-O_8CDD	60	6000	
NWQL	C13-2378-T_4CDD	50	1250	25
	C13-12378-P_5CDD	100	2500	
	C13-123678-H_6CDD	100	2500	
	C13-1234678-H_7CDD	100	2500	
	C13-O_8CDD	150	3750	

Duplicate samples were used to assess the reproducibility or precision of measurements within laboratories. Duplicates of selected samples were prepared at the NWQL by subdivision of wet sediment samples (M. Forbes, pers. comm., Environment Canada). Consequently, homogeneity of duplicates could not be guaranteed. Each commercial laboratory analyzed one set of duplicates: sample splits #21B, #22A and #22B were sent to Wellington, Eco Logic and Seakem laboratories, respectively.

Four other duplicate samples, listed below, were analyzed as part of the intralaboratory QC program:

- Wellington laboratory analyzed sample #11B (NORWD-1) in duplicate. This sample was collected at the beginning of the analytical program in support of a screening study.

- Seakem provided, upon request, results for two sediment samples analyzed in duplicate by their laboratory for another program during the same time period.

- reference material samples (see below) were sent in duplicate (QC3A, QC3B) to the commercial laboratories. Eco Logic laboratory results are reported. No results were available from Seakem and Wellington laboratories (samples were lost during cleanup).

Although not specifically designed for assessing reproducibility in the present QA/QC program, the results were considered relevant and valuable because few duplicate samples were analyzed during the program. Again, except QC3A and QC3B, these duplicates were obtained by subdivision of wet sediment samples.

The NWQL QC program includes the analysis of blind triplicate sediment samples. Composite samples were collected from two locations in British Columbia and split into subsamples in the field. Sample numbers A2, A3 and B2, B3 were analyzed during the same period as were the field sediment samples; results are presented by Mah et al. (1989). These data, however, are not suitable for assessing reproducibility since field variation is included thus precluding comparison to the sample split in the laboratory. The RRETC laboratory did not process duplicates.

Bias of data was assessed for the three commercial laboratories using samples of reference material fortified with a known concentration of dioxin and furan.

Reference material samples were prepared by the National Water Research Institute (NWRI, Quality Assurance Project), Burlington, following procedures specifically designed for this type of study. reference material samples #QC1, QC2, QC3A, QC3B were prepared from a soil/sediment composite material that had previously been shown to be subtantially free of, or to contain only very lov levels of 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF. This material was fortified with each of these two compounds to 50 pg/g and 100 pg/g for samples #QC2 and #QC3 respectively. Sample #QC3 was subdivided (QC3A and QC3B). Sample #QC1 was not fortified. Since the reference material is sieved and dry, and the spiking procedure is rigorously controlled, it is assumed,although not statistically validated, that error attributable to sample heterogeneity is minimized. It should be borne in mind that the reference material used is not certified.

To determine the interlaboratory comparability of the data generated by the participating laboratories, replicate sediment samples as described below were prepared and sent to the laboratories.

Wet sediment replicates were made from samples collected at three sites: #11B (Fraser River, BC), #40A (Mistassini River, Quebec), #21A (Wapiti River, Alberta). Samples were subdivided in the field after thoroughly mixing using a spoon. Sample #11B was sent to the three commercial laboratories and the NWQL as part of the laboratory screening study. Replicates of sample #40A were analyzed by all three commercial laboratories, however a replicate of sample #21A was not sent to the Seakem laboratory. Samples split in the field can not be guaranteed homogeneity.

Complete analyses of all the congener-groups (tetra to octachlorinated dioxin and furan) were also performed on the reference material (sample QC1, QC2 and QC3). These data can be used to assess the interlaboratory comparability of the results. A better homogeneity of the replicate samples is expected in this case.

It should be noted that QC samples (duplicates, replicates, reference material) were not submitted to the laboratories as blind samples.The laboratory and analyst involved were aware of the identity of each sample submitted.

2. QUALITY ASSURANCE/QUALITY CONTROL RESULTS

2.1 Intralaboratory Quality Control

Internal laboratory quality control procedures are described in the laboratory reports available on request. Results are summarized and discussed below.

- Eco Logic, Seakem and the NWQL laboratories provided results for one method blank sample conducted at the same time as the sediment analysis, while RRETC and Wellington laboratories provided two method blanks. No dioxins or furans were detected in the blank samples. However, a potential contamination problem was encountered for Seakem as the blank sample showed positive results for congener group T_4CDF (20 pg/g detected, detection limit of 16 pg/g) and O8CDD (180 pg/g detected, detection limit of 92 pg/g).

- Results for method spikes were provided by the NWQL laboratory only. The method spike showed recoveries in the range of 52-63% for all surrogates.

- The performance standard recovery (13C12-1234-T_4CDD) results were available from the RRETC and the NWQL laboratories only. The mean recoveries were 109% and 102% respectively with low coefficients of variation of 6% and 13%.

- The analytical procedure for dioxin and furan requires the addition of a set of surrogate standards (isotopes labelled with carbon 13) to each sediment sample. This method allows the calculation of mean values of recovery of standards as well as the standard deviation. Results are presented in Table D-2, along with the quantity of surrogate added. Average surrogate recoveries for tetra through octa congeners were between 45 and 95% . Coefficients of variation (C.V.) of the recoveries were relatively low (8-30%) which suggested that analytical procedures were consistent. An interlaboratory comparison study on measurement of CDD/CDF in pulp and paper matrices showed recoveries ranging from 56-84% and C.V. from 9-53% (Chiu et al., 1989).

TABLE D-2. Recoveries of Surrogate Standards, Mean, Range, Standard Deviation and Coefficient of Variation (C.V.) in %.

Laboratory	# of Spikes samples	Parameters	Recovery Mean (%)	Recovery Range (%)	Recovery Standard Deviation (%)	Recovery C.V. (%)
Wellington	29	C13-2378-T_4CDD	79	43-115	16.8	21
	29	C13-12378-P_5CDD	87	38-129	19.2	22
	29	C13-123678-H_6CDD	90	49-136	18.3	20
	29	C13-1234678-H_7CDD	84	50-117	18.0	21
	29	C13-O_8CDD	70	27-162	23.6	34
Seakem	21	C13-2378-T_4CDD	79	50-100	11.5	15
	21	C13-2378-T_4CDF	81	89-100	12:1	15
	21	C13-12378-P_5CDD	68	48-87	12.0	18
	21	C13-123678-H_6CDD	68	42-90	15.1	22
	21	C13-1234678-H_7CDD	63	35-95	15.6	25
	21	C13-O_8CDD	52	30-78	14.3	28
Eco Logic	33	C13-2378-T_4CDD	93	52-135	21.2	22
	33	C13-12378-P_5CDD	82	30-142	25.8	31
	33	C13-123678-H_6CDD	82	20-141	26.3	32
	33	C13-1234678-H_7CDD	70	20-132	25.4	36
	33	C13-O_8CDD	46	19-86	21.2	46
RRETC	15	C13-2378-T_4CDD	82	62-95	7.1	9
	15	C13-12378-P_5CDD	86	72-105	9.7	11
	15	C13-123678-H_6CDD	87	71-110	10.7	12
	15	C13-1234678-H_7CDD	79	54-107	13.0	17
	15	C13-O_8CDD	79	65-106	10.0	13
NWQL	45	C13-2378-T_4CDD	82	28-119	17.9	22
	45	C13-12378-P_5CDD	75	12-125	23.1	31
	45	C13-123678-H_6CDD	63	5-120	25.8	41
	45	C13-1234678-H_7CDD	57	10-118	24.7	43
	45	C13-O_8CDD	52	18-125	24.1	47

Reproducibility of the analytical results, as assessed by duplicate sediment samples, are shown in Tables D-3a and D-3b for dioxin and furan respectively. It should be noted that these results represent a combination of random analytical error (instrumentation, extraction, cleanup, etc.) of repetitive measurements and variability associated with sample heterogeneity. Wet sediment samples are difficult to subsample homogeneously and this may explain, in part, the variability observed among results. Sample heterogeneity can be assessed, to some degree, by examining physical characteristics of the sediments (Appendix I). Results for particle size distribution and organic carbon contents in the duplicate samples #21B, #22A and #22B indicated that good sample homogeneity was obtained.

Reproducibility can be represented for each duplicate sample set by calculation of the deviation from the mean. When one value of the duplicate pair was reported as 'less than detection limit' the difference is assumed to be 0% if the detection limits for the pair of data are equal. Otherwise, no estimation of the deviation is calculated.

It should be noted that analytical variability of repetitive measurements of CDDs and CDFs at the pg/g (ppt) level is expected and acceptable (to a certain extent). When looking at the results on Tables D-3a and D-3b, we have to consider that these are real samples and the matrices encountered are never truly homogeneous. Also, analytical variance increases when concentrations approach the method detection limit.

Based on actual analytical experience, at contaminant levels of 10 pg/g, a deviation of $\pm$ 100% is judged acceptable, while at levels of approximately 100 pg/g, deviation of $\pm$ 25% is expected (M.A Forbes, pers. comm., Environment Canada). These limits can be used to define the acceptable degree of reproducibility between duplicate samples although they are arbitrary and not documented by a long history of data. No QC requirement or criterion for precision was established prior to this study. The QA protocol for effluent, pulp and sludge analysis in the program (Sergeant, 1989) set acceptance of duplicate results at $\leq$50% relative difference.

Based on the limited number of duplicate samples submitted, results appear to indicate good laboratory performance for reproducibility, with deviations from the mean of less than 10% being reported in most cases for dioxin and furan analysis. Specific comments are as follows:

- Duplicate measurements for 2,3,7,8-T_4CDD and total T_4CDD exhibited good reproducibility (deviation <10%). At low contaminant levels (near or below detection limit), the three commercial laboratories reported results with minimal variability (0%).

Table D-3a. INTRALABORATORY QUALITY CONTROL: RESULTS ON DUPLICATE SEDIMENT SAMPLES

DIOXIN CONCENTRATION (pg/g dry weight)

Laboratory	Sample No.	2,3,7,8-T4CDD results		2,3,7,8-T4CDD deviation*	Total T4CDD results		Total T4CDD deviation	Total P5CDD results		Total P5CDD deviation	Total H6CDD results		Total H6CDD deviation	Total H7CDD results		Total H7CDD deviation	Total O8CDD results		Total O8CDD deviation
WELLINGTON	21B[1]	L5	L6	-[2]	5	5	0%	L2	L2	0%	L5	6	-	L8	L5	-	L9	L20	-
	#11B[1]	12	12	0%	12	12	0%	L16	L13	-	40	40	0%	10	21	36%	31	37	9%
BCD LOGIC	22A[1]	L1	L1	0%	L1	L1	0%	L1	L1	0%	L1	L1	0%	22	59	46%	7	180	93%
	QC3A-3B[3]	120	100	9%	120	100	9%	L4	L3	-	L4	26	-	84	140	25%	410	350	8%
SEAREM	22B	L2	L2	0%	L2	L2	0%	L2	L3	-	L4	L5	-	15	9	25%	130	75	26%
	-[4]	1	1	0%	1	1	0%	L1	L2	-	720	770	3%	120	110	4%	440	410	4%
	-[4]	L9	L1	-	L9	L1	-	L12	L1	-	43	47	4%	L16	L12	-	L60	L60	0%

L denotes less than the specified detection limit indicated immediately after
* deviation = (value - mean)/ mean x 100

(1) wet sample split in the laboratory
(2) deviation not calculated due to results lower than detection limit
(3) dry sample
(4) samples not included in the survey

Table D-3b. INTERLABORATORY QUALITY CONTROL: RESULTS ON DUPLICATE SEDIMENT SAMPLES

FURAN CONCENTRATION (pg/g dry weight)

Laboratory	Sample No.	2,3,7,8-T4CDF results		deviation*	Total T4CDF results		deviation	Total P5CDF results		deviation	Total H6CDF results		deviation.	Total H7CDF results		deviation	Total O8CDF results		deviation
WELLINGTON	21B(1)	36	32	6%	50	54	4%	L2	L3	-(2)	L1	L1	0%	L2	L2	0%	L2	L6	-
	011B(1)	210	200	2%	310	320	2%	L6	L16	-	L2	L2	0%	L2	L3	-	L4	L5	-
BCD LOGIC	22A(1)	L1	L1	0%	L1	L1	0%	L1	L1	0%	L1	L1	0%	L1	L1	0%	L3	L5	-
	QC3A-3B(3)	120	110	4%	120	110	4%	L3	L4	-	L4	20	-	L5	92	-	120	110	4%
SEAKEM	22B	7	2	56%	7	2	56%	L2	L2	0%	2	L2	-	5	L3	-	7	L4	-
	-(4)	140	130	4%	200	190	3%	L2	L2	0%	22	38	27%	66	71	4%	16	22	16%
	-(4)	7	4	27%	7	6	15%	L8	L3	-	L18	L13	-	L13	L18	-	L28	L39	-

L denotes less than the specified detection limit indicated immediately after
* deviation = (value - mean)/mean x 100

(1) wet sample split in the laboratory
(2) difference not calculated due to results lower than detection limit
(3) dry sample
(4) samples not included in the survey

- The same comments apply to 2,3,7,8-T_4CDF and Total T_4CDF duplicate results although higher deviations from the mean (56% and 27%) were observed in certain cases at low concentrations (near detection limit).

- Higher deviations (average of 30%) are observed for higher chlorinated dioxins (Total H_7CDD and O_8CDD) than for lower chlorinated dioxins.

- It should be noted that levels of penta to octachlorinated furans in duplicate sets were generally less than the detection limit. The few sample sets with values higher than the detection limit showed an acceptable degree of reproducibility (deviations 4% to 27%).

Levels of dioxin and furan were less than the detection limit for half of the duplicate samples submitted. Reproducibility of data for values less than the detection limit can only be judged by consistency of the detection limit value. Reproducibility of the detection limit was good with most data sets exhibiting identical detection limits (e.g. L2,L2) or by differing by less than three pg/g (e.g. L3,L5).

For seven sets of duplicate results, precision cannot be calculated because a value 'less than' detection limit and a value 'greater' than detection limit was reported. While differences were minimal for four of the sets, Eco Logic reported larger differences for the congeners H_6CDD, H_6CDF and H_7CDF in duplicate samples QC3A and QC3B analyzed by Eco Logic laboratory. The poor reproducibility observed in these latter cases may be attributed to a lack of consistency in the laboratory since sample homogeneity can be assumed good for reference material.

2.2 Interlaboratory Quality Control

Bias and data comparability between laboratories were assessed by reference material and replicate samples. Results for the interlaboratory quality control samples are shown in Tables D-4a, D-4b and D-5.

The low number of interlaboratory quality control samples and participating laboratories precludes using statistical techniques (mean and coefficient of variation) to evaluate results. Therefore, assessment of the interlaboratory quality control is restricted to a qualitative description of results.

Considering the previous observations on intralaboratory reproducibility (Section 2.1), the QC results given in Tables D-4a, D-4b and D-5 appear to indicate that bias and comparability are satisfactory; overall 75% of the data sets are in general agreement. Limits of an acceptable degree of variability among results from laboratories for dioxin and furan analysis have not been defined. A detailed assessment of the interlaboratory quality control results is required to detect the presence of systematic bias and to determine if the congener groups analyses reveal different degrees of variability. Reference material and replicate wet sample results will be assessed separately because subsampling techniques were different.

2.2.1 REFERENCE MATERIAL SAMPLES

Tables D-4a and D-4b present analytical results on the four Quality Control samples (reference material QC1, QC2, QC3A, QC3B) submitted to the three commercial laboratories.

The bias of analysis is evaluated with results on fortified reference material samples (at concentrations of 50 and 100 pg/g):

- Results on the fortified samples showed that laboratories were generally within an average of 20% of the expected values.
- At the 100 pg/g level of 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF, all laboratories provided data (range of 90-120 pg/g) with satisfactory accuracy.
- At the 50 pg/g level of 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF, Seakem laboratory had a detection problem probably attributed to clean up deficiency in the method or less than desirable conditions for the instrumentation (A.S.Y. Chau, pers. comm., NWRI). Eco Logic laboratory, for 2,3,7,8-T_4CDD was biased high by nearly 100% (reported value 98 pg/g).

Comparability can be assessed by using results for the other dioxin and furan congeners (tetra to octachlorinated).

- Results for total tetrachlorinated dioxins and furans were similar to those for 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF showing that the reference material used was virtually free of other tetrachlorinated congeners.

TABLE D-4a. INTERLABORATORY QUALITY CONTROL: DIOXIN RESULTS ON REFERENCE MATERIAL SAMPLES

DIOXIN RESULTS FOR SAMPLE QC1 **

Laboratory	DIOXIN CONCENTRATION (pg/g dry wt.)					
	2378 T4CDD	total T4CDD	total P5CDD	total H6CDD	total H7CDD	total O8CDD
Seaken	L18	L18	L30	L50	63	840
Wellington	L50	L3	L3	38	150	660
Eco Logic	18	18	L4	75	270	690

** Not fortified

DIOXIN RESULTS FOR SAMPLE QC2 **

Laboratory	DIOXIN CONCENTRATION (pg/g dry wt.)					
	2378 T4CDD	total T4CDD	total P5CDD	total H6CDD	total H7CDD	total O8CDD
Seaken	L34	L34	L58	L140	120	800
Wellington	64	43	L6	33	130	480
Eco Logic	98	98	L3	21	120	570

** Fortified with 50 pg/g each of 2,3,7,8-T4CDD

DIOXIN RESULTS FOR SAMPLE QC3A **

Laboratory	DIOXIN CONCENTRATION (pg/g dry wt.)					
	2378 T4CDD	total T4CDD	total P5CDD	total H6CDD	total H7CDD	total O8CDD
Seaken (1)	NA (3)	NA	NA	NA	NA	NA
Wellington	110	84	L4	27	150	550
Eco Logic	120	120	L4	L4	84	410

** Fortified with 100 pg/g each of 2,3,7,8-T4CDD

DIOXIN RESULTS FOR SAMPLE QC3B **

Laboratory	DIOXIN CONCENTRATION (pg/g dry wt.)					
	2378 T4CDD	total T4CDD	total P5CDD	total H6CDD	total H7CDD	total O8CDD
Seaken	91	91	23	98	130	930
Wellington (2)	NA	NA	NA	NA	NA	NA
Eco Logic	100	100	L3	26	140	350

** Fortified with 100 pg/g each of 2,3,7,8-T4CDD

L denotes less than the specified detection limit indicated immediately after

(1) Sample QC3A lost. No result available

(2) Sample QC3B lost during cleanup - no result available

(3) NA - Not available

TABLE D-4b. INTERLABORATORY QUALITY CONTROL: FURAN RESULTS ON REFERENCE MATERIAL SAMPLES

FURAN RESULTS FOR SAMPLE QC1 **

Laboratory	FURAN CONCENTRATION (pg/g dry wt.)					
	2378 T4CDF	total T4CDF	total P5CDF	total H6CDF	total H7CDF	total O8CDF
Seahen	L16	L16	L22	L30	100	120
Wellington	L10	31	16	47	72	150
Eco Logic	L4	18	L4	45	140	170

**Not fortified

FURAN RESULTS FOR SAMPLE QC2 **

Laboratory	FURAN CONCENTRATION (pg/g dry wt.)					
	2378 T4CDF	total T4CDF	total P5CDF	total H6CDF	total H7CDF	total O8CDF
Seahen	L30	L30	L42	L84	L93	140
Wellington	59	68	11	28	62	150
Eco Logic	93	83	L3	18	36	110

** Fortified with 90 pg/g each of 2,3,7,8-T4CDF

FURAN RESULTS FOR SAMPLE QC3A **

Laboratory	FURAN CONCENTRATION (pg/g dry wt.)					
	2378 T4CDF	total T4CDF	total P5CDF	total H6CDF	total H7CDF	total O8CDF
Seahen (1)	NA(3)	NA	NA	NA	NA	NA
Wellington	94	100	12	26	79	150
Eco Logic	120	120	L4	L4	L5	120

** Fortified with 100 pg/g each of 2,3,7,8-T4CDF

FURAN RESULTS FOR SAMPLE QC3B **

Laboratory	FURAN CONCENTRATION (pg/g dry wt.)					
	2378 T4CDF	total T4CDF	total P5CDF	total H6CDF	total H7CDF	total O8CDF
Seahen	120	130	95	130	100	140
Wellington (2)	NA	NA	NA	NA	NA	NA
Eco Logic	110	110	L3	20	92	110

** Fortified with 100 pg/g each of 2,3,7,8-T4CDF

L denotes less than the specified detection limit indicated immediately after

(1) Sample QC3A lost. No result available

(2) Sample QC3B lost during cleanup - no result available

(3) NA - Not available

- The QC samples submitted contained only low concentrations (near detection limit) of penta and hexachlorinated dioxins and furans (P_5CDD, P_5CDF, H_6CDD, H_6CDF). At low levels, data sets were in general agreement and laboratories produced comparable results. However, P_5CDF, H_6CDF and H_6CDD results reported by Seakem laboratory for the sample QC3B were again biased high constituting the only outlier results. Moreover, Seakem experienced difficulty with detection limits in the analysis of samples QC1 and QC2.

- For H_7CDF, H_7CDD and O_8CDF analysis, QC samples contained detectable dioxin and furan concentrations (approximately 50-150 pg/g). Comparable data were reported by the laboratories. Only Eco Logic reported outlier results for the analysis of H_7CDF in sample QC3A.

- The QC samples contained high concentrations of congener O_8CDD (400-800 pg/g) and the laboratories reported comparable results. Seakem results on O_8CDD appears to be systematically higher than the other laboratories.

Recently, a National Dioxin Quality Control Study (Stokker and Chau, 1989) was conducted by National Water Research Institute (Quality Assurance Group). Sediment samples were prepared with reference material using procedures and spiking levels identical to those for #QC2 and #QC3. Preliminary results on analysis for dioxins and furans in sediments are presently available. Ten commercial and government laboratories were involved. Environment Canada laboratories the National Water Quality Laboratory (Burlington) and the River Road Environmental Technology Centre (Ottawa), and commercial laboratories; Wellington Environmental Consultants Inc. and Eco Logic Laboratory Inc., participated in the study.

The National Dioxin Quality Control Study No.1 (Stokker and Chau, 1989) was the first one conducted on sediments. Consequently, the Quality Assurance/Quality Control database for analysis of dioxin and furan in sediments is not based on long term analytical experience. It is useful, however, to compare the interlaboratory variability observed in the two QC studies and verify if results exhibit similar trends at comparable contaminant levels. Combining the results of the two QC studies will permit a better assessment of the interlaboratory variability using a more extensive database. It is also a good reference for judging the acceptability of the present study data.

Results from National Dioxin QC Study No.1, although performed at a different time (summer 1989), will account for the absence of analyses from RRETC and NWQL on reference material (bias and comparability of

results). It is important to note that the use of data from this study to assess RRETC and NWQL performance assumes that the overall competence of the laboratories over time is steady.

In both QC studies, data indicate similar variability for the interlaboratory results. Therefore, it is assumed that interlaboratory variability observed in the present study is acceptable although not quantified. Preliminary results from Stokker and Chau (1989) study are briefly discussed below.

- For the 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF fortified sample at 100 pg/g level, Stokker and Chau (1989) reported values in the same range (80-150 pg/g) with a similar bias (within 30%) as data reported in the present study (Environment Canada 1990). At 50 pg/g concentration, bias increased and larger differences from the design values ($\pm$70%) were observed for the analysis of 2,3,7,8-T_4CDD. All results on fortified samples from RRETC and NWQL laboratories were satisfactory (generally within 20%).

- Stokker and Chau (1989) reported a variability similar to the present study (Environment Canada 1990) for P_5CDD,H_6CDD,P_5CDF and H_6CDF when the concentrations were near the detection limit. Both RRETC and NWQL reported not detected values as did the majority of participants. Outlier results occurred also: RRETC laboratory was biased high for P_5CDF and H_6CDF in one of the two samples submitted for the study.

- Analytical results reported by laboratories in the Stokker and Chau study (1989), with similar concentrations for H_7CDD,H_7CDF and O_8CDF, were comparable and showed similar variability. RRETC and NWQL laboratories compared well with one another and with other participants.

- Finally, the majority of the participants in the Stokker and Chau study showed comparable results for high concentrations of O_8CDD (250-550 pg/g). RRETC and NWQL laboratories provided results with a satisfactory comparability.

2.2.2 REPLICATE WET SAMPLES

Interlaboratory quality control was also assessed using replicate wet samples (Table D-5). Prior to any interpretration of results, homogeneity of replicate samples must be established as differences in physical characteristics can influence analytical results. Physical characteristics of sediments (particle size and organic carbon content) are given in Appendix I. Results for samples #11B and #40 indicate that replicates were not homogeneous. For sample #11B, the replicate sent to NWQL contained higher percentages of organic carbon and clay than the replicate sent to Eco Logic laboratory.

TABLE D-5. INTERLABORATORY QUALITY CONTROL: DIOXIN and FURAN RESULTS ON REPLICATE OF WET SEDIMENT SAMPLES SPLIT IN THE FIELD

Sample No.	Laboratory	DIOXIN CONCENTRATION (pg/g dry wt.) 2378 T4CDD	total T4CDD	total P5CDD	total H6CDD	total H7CDD	total O8CDD
11B (Norwd-1)	Wellington	12	12	L16	40	10	31
	Eco Logic	L5	L5	L5	L8	17	L10
	Seakem	5	5	L6	13	20	95
	NWQL	L15	L15	L20	L30	L50	L75
40A	Wellington	L10	2	L3	L2	L9	L40
	Eco Logic	L2	2	L2	19	68	72
	Seakem	L3	L3	L9	8	26	410
21A	Wellington	L1	L1	L2	L4	L5	L20
	Eco Logic	L2	L2	L2	L2	L5	L16

Sample No.	Laboratory	FURAN CONCENTRATION (pg/g dry wt.) 2378 T4CDF	total T4CDF	total P5CDF	total H6CDF	total H7CDF	total O8CDF
11B (Norwd-1)	Wellington	210	310	L6	L2	L2	L5
	Eco Logic	230	520	L3	L4	L6	L8
	Seakem	180	290	L4	L4	L14	L12
	NWQL	274	406	L15	L25	L40	L75
40A	Wellington	7	6	L1	11	25	L20
	Eco Logic	5	8	L2	5	37	20
	Seakem	13	13	L9	L5	57	46
21A	Wellington	1	1	L1	L1	L2	L4
	Eco Logic	L2	L2	L2	L2	L2	L16

L denotes less than the specified detection limit indicated immediatly after

Unfortunately, results are not available for Seakem and Wellington laboratories. Sample #40A, the replicate sent to Seakem laboratory, contained a lower percentage of clay than replicates sent to the Wellington and Eco Logic laboratories. Replicates of sample #21A were homogeneous according to physical characteristic.

Although in the replicate vet samples, dioxin and furan were not detected or were in very low concentration (except for O_8CDD and 2,3,7,8-T_4CDF), the analytical results are significant since they indicate a good comparability among laboratories. Differences observed for O_8CDD and 2,3,7,8-T_4CDF results can be attributed to the heterogeneity of the samples. This appears to be particularly evident with the large difference of O_8CDD recorded for sample #40 by the Seakem laboratory.

1.3 QA/QC Discussion

Interpretation of QA/QC results is strongly limited by the factors that are discussed below.

- The use of vet sediment material for QC purposes is inappropriate because homogeneity is difficult to obtain as variation in results can be attributed to sample heterogeneity. In addition, the vet samples submitted contained mainly non-detectable levels of CDD/CDF. QC samples should be selected to reflect the reproducibility for a range of detectable values.

- Data reported for the spiked reference materials provided incomplete answers on bias and interlaboratory comparability for 2,3,7,8-T_4CDD. Spiking concentrations were not representative of the low levels encountered in sediment samples. Since less than detection limit values were frequently reported, spikes prepared at levels of the same order of magnitude as the detection limit would have been essential. On the other hand, spiked reference material with 2,3,7,8-T_4CDF were highly relevant considering the levels encountered in the survey.

- There are insufficient observations to assess adequately the quality and comparability of the results. Initially, five QC samples were included with the sample set submitted to each laboratory. However, in addition to inappropriateness of vet samples as mentioned above, results for the reference material samples were incomplete (two laboratories lost one of the QC samples) or reported values with an unsatisfactory sensitivity

(detection limit too high). For these reasons, QC sample frequency was significantly less than planned and the interpretation process is seriously hampered considering the low number of samples and participants involved in the analysis. **The actual interlaboratory quality control results do not constitute a complete database and could not document the overall competency of the participating laboratories.**

- The fact that QC activities were not processed as 'blind' samples may potentially lead to higher quality results than is the normal case for the laboratory.

- Since a standard reference material (S.R.M.) for CDD/CDF in sediments is not available, no statement can be made concerning the accuracy of the method used by each laboratory. In the absence of an S.R.M., the use of spiked reference material constituted an option to estimate bias. It is considered the equivalent of an S.R.M. as far as preparation is concerned, although a 'certified' value was not determined.

The analytical procedure for dioxin and furan analysis is long and involves numerous sample preparation and clean-up steps with which errors can be associated. Another source of error lies in the different instrumentation used by the laboratories. There were also differences in the type and intensity of intralaboratory QC procedures. At ultra-trace levels, small differences in clean-up procedures or instrument maintenance can lead to a variable sensitivity and fluctuation in the detection limit.

Other factors to be considered when looking at interlaboratory comparability of results are mentioned below:

- Common and accurate standard solutions (surrogate, performance and quantitation standard) were not provided to the laboratories by Environment Canada.
- Amount (concentration and quantity) of surrogates spiked into the samples varied from laboratory to laboratory.
- Acceptable and predetermined detection limits were not rigorously established.

Considering the low number of samples analyzed, number of participants involved and limitations for the assessment, it is considered relevant to complement the QA/QC discussion with results obtained in the recent Interlaboratory comparison study on the measurements of PCDD/PCDF in pulp and paper matrices (Chiu et al. 1989). The study was conducted in two parts to investigate the comparability of analytical procedures and results produced by various Canadian government and commercial laboratories. Blind standard solutions and sample matrix (pulp and sludge) were used.

- During the first part of the study, standard solutions (consisting of 10 isomers covering tetra to octa homologues) with a design value of 100 pg/uL (ppt) were analyzed. Results showed that coefficients of variation of 28% and 49% were obtained for 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF. For the other congener groups, variation was greater and ranged from 28% to 65%.

- Pulp matrix samples submitted contained only low levels of 2,3,7,8-T_4CDD. Variability of the results reported by the laboratories (L50, L38, 40, 12, 10, 10) were related to large differences in the sensitivity of the analytical methods. For 2,3,7,8-T_4CDF, a C.V. of 45% was estimated with a mean value of 350 pg/g.

- In sludge samples, higher values of 2,3,7,8-T_4CDD were detected (mean of 200 pg/g) with a C.V. of 35%. The hepta and octa chlorinated dioxins analysis, with mean concentrations of 225 and 1700 pg/g, showed a C.V. of 67% and 40% respectively.

- The second part of the interlaboratory study on pulp and paper matrices showed that agreement and credibility of data were enhanced as a result of providing common and accurate standard solutions for calibration, and specifying mandatory requirements and key elements of quality assurance and analytical procedures. Under controlled conditions, coefficients of variation were subtantially reduced and improved (by 13% to 56%).

Findings of the Interlaboratory study on pulp and paper matrices (Chiu et al. 1989) discussed above cannot be directly correlated to the present sediment survey results as each matrix requires different sample extraction and clean-up procedures, and analytical sensitivity also varies. In addition, analytical procedures used in the present study were not equivalent to those used in the Interlaboratory study. In general, the analytical procedures were similar but some elements were not followed explicitly and may have been a cause of the greater variability.

The Interlaboratory study on pulp and paper matrices, however, gives indications of the potential range of interlaboratory variabilities obtained under specific conditions. It also provides a broader perspective and reference with which we can assess results produced by the QA/QC activities during the present sediment contamination survey.

In that respect, overall statements on the quality of the data obtained for the sediment survey, based on the QA/QC results and previous discussions, are the following:

1) For the QC samples presenting low levels of 2,3,7,8-T_4CDD, large differences in detection limits among laboratories and large discrepancies from the design value suggest that data provided by the commercial laboratories could be less accurate and not comparable in certain cases. At low levels of 2,3,7,8-T_4CDF, accuracy and comparability seem to indicate slightly better results but not sufficiently documented to conclude on the quality of these analysis.

2) At levels equal to or greater than 100 pg/g of 2,3,7,8-T_4CDD and 2,3,7,8-T_4CDF, analytical performance of the laboratories is considered acceptable; good accuracy and comparability ($\pm$ 20%) of the results was obtained.

3) For the other congener groups of dioxins and furans (penta to octa chlorinated) interlaboratory variation is greater ($\pm$50%) and outlier values are more predominant.

Although results of the reduced QA/QC activity carried out for the present sediment study are partly acceptable, a more expanded program, conducted prior to sediment sample analyses, would have been highly desirable to increase confidence in the data and maximize the generation of quality analytical data. Also, it must be recognized that the design of the QA/QC study is confusing because there was an absence of clearly defined objectives and various activities were not properly coordinated and managed. In addition, there was insufficient ongoing evaluation of the data from the laboratories and consequently there was a failure to identify problems and recommend corrective actions in a timely manner. Most of the problems in QA/QC resulted to a large extent from not having clear and continuous project management responsibilities. More stringent and continuous control on work carried out by the laboratories would have been required to ensure that QA/QC requirements were effectively followed and performance was satisfying.

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APPENDIX E
LIST OF ANALYTICAL LABORATORIES AND CODIFICATION OF SEDIMENT SAMPLES

Appendix E Codification and Analytical Laboratory List for Sediment Samples

DOE[1] No.	Field sample[2] code	Analytical[3] code	Laboratory[4]		
			Dioxins/Furans	Particle size	Organic carbon
1A	Elk Falls - Site A	323-22	SEAK	NA	SOILC
1B	Elk Falls - Site C	323-23	SEAK	SOILC	SOILC
1C	Elk Falls - Painter's Lodge	323-21	SEAK	SOILC	SOILC
2A	Crofton A - Dryland Sort	CROFTON A	RRETC	WR-R	NWQ
2AA	BCFP Crofton Sampler	CDS-8	CWS	-	-
2B	Crofton B - off outfall	CROFTON B	RRETC	WR-R	NWQ
2C	Crofton C - off South Wharf	CROFTON C	RRETC	WR-R	NWQ
3A	Gold River - Jacklah Bay	323-19	SEAK	SOILC	SOILC
3B	Gold River - In front of G.R. Pulp Mill	323-20	SEAK	SOILC	SOILC
4A	-	-	NWQ	WR-V	NWQ
4B	-	-	NWQ	WR-V	NWQ
4C	-	-	NWQ	WR-V	NWQ
4D	-	-	NWQ	WR-V	NWQ
4E	-	-	NWQ	WR-V	NWQ
4F	-	-	NWQ	WR-V	NWQ
5A	KITU-01	8909369	NWQ	WR-V	NWQ
5B	KITU-02	8909370	NWQ	WR-V	NWQ
5C	KITU-03	8907371	NWQ	WR-V	NWQ
5D	EUR-01	8907372	NWQ	WR-V	NWQ
5E	EUR-02	8907373	NWQ	WR-V	NWQ
5F	EUR-03	8907374	NWQ	WR-V	NWQ
5G	Kitimat-7 (Stn 10)	-	NWQ	WR-V	NWQ
5H	Kitimat-20(D)	-	NWQ	WR-V	NWQ
5I	Kitimat-21(E)	-	NWQ	WR-V	NWQ

(1)Site number attributed by Department of Environment and used along this report
(2)Code or identification as indicated on Field Sample Labels
(3)Code attributed by the Analyical Laboratory and indicated in the analytical reports
(4)Identification of the laboratory which performed analysis

LEGEND

Dioxins/Furans

SEAK	Seakem Ltd.
RRETC	River Road Environmental Technology Centre
NWQ	National Water Quality Laboratory (Burlington)
ECOL	Eco Logic Inc.
WELL	Wellington Inc.
CWS	Canadian Wildlife Service
USEPA	United States Environmental Protection Agency

Particle size /Organic carbon

SOILC	Soilcon Laboratory Ltd.
XRAL	XRAL Environmental
NWQ	National Water Quality Laboratory (Burlington)
WR-V	Water Resources Branch Laboratory - Vancouver
WR-R	Water Resources Branch Laboratory - Regina

Appendix E Cont'd

DOE[1] No.	Field sample[2] code	Analytical[3] code	Laboratory[4]		
			Dioxins/Furans	Particle size	Organic carbon
6A	-	-	NWQ	WR-V	NWQ
6B	-	-	NWQ	WR-V	NWQ
6C	-	-	NWQ	WR-V	NWQ
6D	-	-	NWQ	WR-V	NWQ
6E	-	-	NWQ	WR-V	NWQ
6F	-	-	NWQ	WR-V	NWQ
7A	M&B Harmac A	HARMAC A	RRETC	WR-R	NWQ
7AA	M&B Harmac - Station A	CDS-10	CWS	-	-
7B	M&B Harmac B	HARMAC B	RRETC	-	-
7C	M&B Harmac C	HARMAC C	RRETC	-	-
8A	M&B Port Alberni - C	BCS-12	RRETC	-	-
9A	Canfor - Port Mellon #1	BCS-17	RRETC	WR-R	NWQ
9B	Canfor - Port Mellon #2	BCS-18	RRETC	WR-R	NWQ
10A	PR-3	BCS-15	RRETC	-	-
11A	-	BCS-10	RRETC	WR-R	NWQ
11B	-	-	NWQ	WR-V	NWQ
11C	-	-	NWQ	WR-V	NWQ
11D	-	-	NWQ	WR-V	NWQ
12/13A	-	-	NWQ	WR-V	NWQ
12/13B	-	-	NWQ	WR-V	NWQ
12/13C	-	-	NWQ	WR-V	NWQ
12/13D	-	BCS-10	RRETC	WR-R	NWQ
12/13E	-	-	NWQ	WR-V	NWQ
12/13F	-	-	NWQ	WR-V	NWQ
12/13G	-	-	NWQ	WR-V	NWQ
14A	Rupert Site #1 - Sample 1A	323-15	SEAK	SOILC	SOILC
14B	Rupert Site #2 - Sample 2A	323-16	SEAK	SOILC	SOILC
15A	-	BCS-11	RRETC	NA	NA
15B	-	-	NWQ	WR-V	NWQ
15C	-	-	NWQ	WR-V	NWQ
15D	-	-	NWQ	WR-V	NWQ
16A	-	-	NWQ	WR-V	NWQ
16B	-	-	NWQ	WR-V	NWQ
16C	-	-	NWQ	WR-V	NWQ
16D	-	-	NWQ	WR-V	NWQ
16E	-	-	NWQ	WR-V	NWQ

Appendix E Cont'd

DOE[1] No.	Field sample[2] code	Analytical[3] code	Laboratory[4]		
			Dioxins/Furans	Particle size	Organic carbon
17A	Woodfibre - A	BCS-19	RRETC	NA	NA
17B	Woodfibre - B	BCS-20	RRETC	WR-R	NWQ
17C	Squamish Hbr.	BCS-21	RRETC	WR-R	NWQ
18A	-	-	NWQ	WR-V	NWQ
18B	-	-	NWQ	WR-V	NWQ
18C	-	-	NWQ	WR-V	NWQ
19A	-	-	NWQ	WR-V	NWQ
19B	-	-	NWQ	WR-V	NWQ
19C	-	-	NWQ	WR-V	NWQ
19D	-	-	NWQ	WR-V	NWQ
19E	-	-	NWQ	WR-V	NWQ
19F	-	-	NWQ	WR-V	NWQ
20A	-	-	NWQ	WR-V	NWQ
20B	-	-	NWQ	WR-V	NWQ
20C	-	-	NWQ	WR-V	NWQ
20D	-	-	NWQ	WR-V	NWQ
20E	-	-	NWQ	WR-V	NWQ
21A	Wapiti - Upstream	89-00175	ECOL	WR-R	XRAL
21AA	Wapiti - Upstream	3	WELL	WR-R	XRAL
21B	Wapiti - Downstream A	1	WELL	WR-R	XRAL
21BB	Wapiti - Downstream B	2	WELL	WR-R	XRAL
22A	Athabasca (above) A	89-00173	ECOL	WR-R	XRAL
22AA	Athabasca (above) B	89-00174	ECOL	WR-R	XRAL
22B	Athabasca - Downstream "A"	323-08	SEAK	SOILC	SOILC
22BB	Athabasca - Downstream "B"	323-09	SEAK	SOILC	SOILC
22C	Athabasca Lake	90-00745	NWQ	WR-R	NWQ
23A	North Saskatchewan River	323-04	SEAK	SOILC	SOILC
24A	Sask. U. Strm	14210	NWQ	WR-V	NWQ
24B	Sask. D. Strm	14211	NWQ	WR-V	NWQ
25A	DC01	8911882	NWQ	WR-V	NWQ
25B	DC02	8911883	NWQ	WR-V	NWQ
25C	DC03	8911884	NWQ	WR-V	NWQ
26A	Wabigoon L. US #4	23	WELL	WR-R	NWQ
26B	Clay Lake DS #5	19	WELL	WR-R	NWQ
26C	Clay Lake DS #6	20	WELL	WR-R	NWQ
26D	Wabigoon R. DS #1	21	WELL	WR-R	XRAL
26E	Wabigoon R. DS #3	22	WELL	WR-R	XRAL

Appendix E Cont'd

DOE[1] No.	Field sample[2] code	Analytical[3] code	Laboratory[4]		
			Dioxins/Furans	Particle size	Organic carbon
27A	EB01	8911870	NWQ	WR-V	NWQ
27B	EB03	8911872	NWQ	WR-V	NWQ
27C	EB02	8911871	NWQ	WR-V	NWQ
28A	RL-1	H	USEPA	NA	NA
28B	RR-3	E	USEPA	NA	NA
28C	SR-1	A	USEPA	NA	NA
28D	4MB-1	B	USEPA	NA	NA
28E	4MB-2	C	USEPA	NA	NA
28F	LW-1	F	USEPA	NA	NA
29A	DS #1 James River Marathon L. Superior	89-00178	ECOL	WR-R	XRAL
29B	DS #2 James River, Marathon	89-00179	ECOL	WR-R	XRAL
29C	DS #3 James River Marathon L. Superior	89-00180	ECOL	WR-R	XRAL
29D	DS #4 James River marathon L. Superior	89-00181	ECOL	WR-R	XRAL
29E	DS #5 James River marathon L. Superior	89-00182	ECOL	WR-R	XRAL
29F	DS #6 Domtar Red Rock (wrong label)	89-0183	ECOL	WR-R	XRAL
30A	DS #1 Domtar Red Rock Nipigon Bay	89-00177	ECOL	WR-R	XRAL
30B	DS #2 Domtar Red Rock Nipigon Bay L. Sup	89-00184	ECOL	WR-R	XRAL
30C	DS #3 Domtar Red Rock Nipigon Bay L. Sup	89-00185	ECOL	WR-R	XRAL
30D	DR01	8911879	NWQ	WR-V	NWQ
30E	DR02	8911880	NWQ	WR-V	NWQ
30F	DR03	8911881	NWQ	WR-V	NWQ
31A	F01	8911869	NWQ	WR-V	NWQ
32A	Moberly Bay DS #1	16	WELL	WR-R	XRAL
32B	Moberly Bay DS #2	17	WELL	WR-R	XRAL
32C	Moberly Bay DS #3	18	WELL	WR-R	NWQ
33A	CPGL01	8911876	NWQ	WR-V	NWQ
33B	CPGL02	8911877	NWQ	WR-V	NWQ
33C	CPGL03	8911878	NWQ	WR-V	NWQ
34A	M01	8911873	NWQ	WR-V	NWQ
34B	M02	8911874	NWQ	WR-V	NWQ
34C	M03	8911875	NWQ	WR-V	NWQ
35A	Q-15	89-00165	ECOL	WR-R	XRAL
36A	Q-14	89-00164	ECOL	WR-R	XRAL
37A	Q-11	89-00162	ECOL	WR-R	XRAL

Appendix E Cont'd

DOE[1] No.	Field sample[2] code	Analytical[3] code	Laboratory[4]		
			Dioxins/Furans	Particle size	Organic carbon
38A	Q-18 (Quevillon)	7	WELL	WR-R	XRAL
39A	Q-16	5	WELL	WR-R	XRAL
40A	Q-10	89-00161	ECOL	WR-R	XRAL
40AA	Q-10	4	WELL	WR-R	XRAL
40AAA	F-10	323-02	SEAK	SOILC	SOILC
41A	Q-17	6	WELL	WR-R	XRAL
42A	Q-12	89-00163	ECOL	WR-R	XRAL
42B	A3115-I	8907378	NWQ	WR-V	NWQ
42C	A3115-II	8907379	NWQ	WR-V	NWQ
42D	A3115-III	8907380	NWQ	WR-V	NWQ
43A	Q-19	8	WELL	WR-R	XRAL
44A	Atlantic-7	89-00167	ECOL	WR-R	XRAL
44B	Atlantic-18	15	WELL	WR-R	XRAL
44C	Atlantic-8	89-00168	ECOL	WR-R	XRAL
44D	Atlantic-16	13	WELL	WR-R	XRAL
45A	Atlantic #2	323-03	SEAK	SOILC	SOILC
45B	Atlantic #1	323-06	SEAK	SOILC	SOILC
45C	Atlantic 17	14	WELL	WR-R	XRAL
46A	Atlantic-9	89-00169	ECOL	WR-R	XRAL
46B	Atlantic-10	89-00170	ECOL	WR-R	XRAL
47A	Atlantic #4	323-07	SEAK	SOILC	SOILC
47B	Atlantic #3	323-05	SEAK	SOILC	SOILC
48A	Atlantic-5	9	WELL	WR-R	XRAL
48B	Atlantic-6	89-00166	ECOL	WR-R	XRAL
49A	Atlantic-15	12	WELL	WR-R	XRAL
49B	Atlantic-14	11	WELL	WR-R	XRAL
50A	Atlantic-11	89-00171	ECOL	NA	XRAL
50B	Atlantic-12	89-00172	ECOL	WR-R	XRAL
51A	Port Alice-Site #1	323-17	SEAK	--	--
51B	Port Alice-Site #2	323-18	SEAK	--	--

APPENDIX F
DIOXIN AND FURAN CONCENTRATIONS IN SEDIMENTS

APPENDIX F-1. Dioxin and Furan Concentrations in Bed Sediments Collected Near the Pulp and Paper Mills.

APPENDIX F-2. Analysis of Individual CDD and CDF Isomers - Concentration in pg/g (dry weight).

APPENDIX F-1

DIOXIN AND FURAN CONCENTRATIONS IN BED SEDIMENTS COLLECTED NEAR THE PULP AND PAPER MILLS

APPENDIX F.1. DIOXIN AND FURAN CONCENTRATIONS IN BED SEDIMENTS COLLECTED NEAR PULP AND PAPER MILLS

Mill and Sampling Location	Specific Site [1]	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
1. Fletcher Challenge (Elk Falls Pulp Division) Strait of Georgia Coastal	A	L3[2]	71	22	330	400	2600	22	31	63	300	570	230
	B	L1	L1	L1	9	6	38	L1	L1	L1	4	14	8
	C	L1	L1	L1	20	7	30	3	3	L1	L1	L2	L4
2. Fletcher Challenge (Crofton Division) Strait of Georgia Coastal	A	L3	L3	23	272	43	45	29	39	L3	L6	L6	L10
	(AA)[3]	(L3)	(L3)	(L5)	(396)	(62)	(60)	(82)	(99)	(L3)	(L3)	(L5)	(L15)
	B	15	126	519	9946	2133	4059	726	1136	66	293	537	394
	C	11	46	283	3250	853	1192	478	682	39	54	63	33
3. Canadian Pacific Forest Prod. (Gold River) Muchalat Inlet Coastal	A	L3	L3	28	620	230	910	360	590	96	360	540	190
	B	2	7	28	400	78	220	430	740	56	35	29	20
4. Weyerhaeuser Canada (Kamloops) Thompson River Upstream	A	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	B	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	C	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
Weyerhaeuser Canada (Kamloops) Thompson River Downstream	D	L15	L15	L20	L30	L50	L75	3168	4521	L15	L25	L40	L75
	E	L15	L15	L20	L30	L50	L75	2445	3459	L15	L25	L40	L75
	F	L15	L15	L20	L30	L50	L75	69	97	L15	L25	L40	L75

(1) Specific site descriptions are given in Appendix A-2.
(2) L denotes values below detection limit: numbers following "L" represent the limit of detection
(3) Duplicate sample (split in laboratory) results in brackets

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
5. Eurocan Pulp and Paper (Kitimat) Kitimat River Upstream	A	L4[2]	L4	L2	L47	L18	L22	L4	L4	L2	L47	L18	L22
	B	L4	L4	L11	L16	L15	L35	L4	L4	L11	L16	L15	L35
	C	L2	L2	L6	L11	L9	L10	L2	L2	L6	L11	L9	L10
Eurocan P&P Kitimat River Downstream	D	L2	L2	L3	L42	L26	L23	L2	L2	L3	L42	L26	L23
	E	L2	L2	L2	L60	L21	L20	L2	L2	L2	L60	L21	L20
	F	L1	L1	L42	578	L15	L17	L1	L2	L42	L68	L15	L17
Eurocan P&P Kitimat Arm Coastal	G[4]	L7	L7	L36	125	L72	105	L7	L7	L36	L62	L72	L78
	H[4]	L28	L28	L470	982	475	932	L28	L28	L470	L103	L79	L186
	I[4]	L6	L6	L37	L92	L50	L60	L6	L6	L37	L92	L50	L60
6. Fletcher Challenge (MacKenzie Pulp Division) Tudyah Lake Upstream	A	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	B	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	C	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
Fletcher Challenge (MacKenzie Pulp Division) Williston Lake Downstream	D	L15	L15	L20	L30	L50	572	2077	3227	51	34	L40	L75
	E	L15	L15	L20	L30	L50	100	982	1570	L15	L25	L40	L75
	F	L15	L15	L20	L30	L50	L75	1081	1725	L15	L25	L40	L75
7. MacMillan Bloedel (Harmac Pulp Division) Strait of Georgia Coastal	A	L3	21	67	760	2049	1987	25	119	161	1784	2324	680
	(AA)[5]	(L3)	(L3)	(42)	(1263)	(1426)	(1197)	(609)	(744)	(L30)	(1080)	(3493)	(798)
	B	4	236	510	3229	1360	1684	288	696	131	520	779	271
	C	L3	99	132	1184	296	251	165	246	12	20	47	15

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection
(4) High detection limit values due to chemical interference
(5) Duplicate sample (split in laboratory) results in brackets

Appendix F.1. (continued)

	Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
8.	MacMillan Bloedel (Alberni Division) Alberni Inlet Coastal	A	8	782	1110	10213	3431	8022	326	817	95	305	463	378
9.	Canfor Port Mellon Pulp (Howe Sound) Coastal	A	17	51	192	5161	720	485	875	1401	14	68	163	33
		B	13	20	69	1756	152	80	897	1345	12	23	10	L10
10.	MacMillan Bloedel (Powell River Division) Strait of Georgia Coastal	A	5	231	364	6230	2327	2958	983	1433	39	364	731	238
11.	Northwood Pulp & Timber (Prince George) Fraser River Downstream	A	L3(2)	L3	L5	L6	L10	16	5	5	L3	L6	L6	L10
		B	L15	L15	L20	L30	L50	L75	274	406	L15	L25	L40	L75
		C	L15	L15	L20	L30	L50	L75	70	101	L15	L25	L40	L75
		D	L15	L15	L20	L30	L50	L75	45	68	L15	L25	L40	L75
12/13.	Canfor Pulp and Inter-Continental Pulp (Prince George) Fraser River Upstream	A	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
		B	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
		C	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	Canfor Pulp and Inter-Continental Pulp (Prince George) Fraser River Downstream	D	L3	L3	L5	L6	L10	16	5	5	L3	L6	L6	L10
		E	L15	L15	L20	L30	L50	L75	51	78	L15	L25	L40	L75
		F	L15	L15	L20	L30	L50	L75	64	64	L15	L25	L40	L75
		G	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
14.	Skeena Cellulose (Prince Rupert) Hecate Strait Coastal	A	L4	L4	L5	790	130	280	340	490	L3	13	19	29
		B	25	25	92	2800	410	930	860	1400	L2	70	45	21

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
15. Cariboo Pulp & Paper (Quesnel) Fraser River Downstream	A	L3[2]	L3	L5	L7	L12	L12	14	19	L5	L7	L7	L10
	B	L15	L15	L20	L30	L50	L75	195	281	L15	L25	L40	L75
	C	L15	L15	L20	L30	L50	L75	159	232	L15	L25	L40	L75
	D	L15	L15	L20	L30	L50	L75	120	176	L15	L25	L40	L75
16. Crestbrook Forest Ind. (Pulp Division) Kootenay River Upstream	A	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	B	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
Crestbrook Forest Ind (Pulp Division) Kootenay River Downstream	C	L15	L15	L20	L30	L50	L75	2217	3655	L15	L25	L40	L75
	D	L15	L15	L20	L30	L50	L75	78	116	L15	L25	L40	L75
	E	L15	L15	L20	L30	L50	L75	27	27	L15	L25	L40	L75
	F	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
17. Western Pulp Partnership (Woodfiber) Howe Sound Coastal	A	27	109	478	16432	1526	721	2005	2257	113	101	102	L30
	B	9	33	146	4538	500	229	3179	4867	28	14	28	L10
	C	L3	L3	L5	1148	122	100	148	219	L5	L7	29	L10
18. Finlay Forest Industries (MacKenzie) Williston Lake Downstream	A	L15	L15	28	L30	L50	94	L10	19	L15	L25	L40	L75
	B	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	C	L15	L15	L20	L30	L50	206	286	672	L15	L25	L40	L75

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
19. Quesnel River Pulp Fraser River Upstream	A	L15[2]	L15	L20	L30	L50	L75	134	192	L15	L25	L40	L75
	B	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	C	L15	L15	L20	L30	L50	L75	37	55	L15	L25	L40	L75
Quesnel River Pulp Fraser River Downstream	D	L15	L15	L20	L30	L50	L75	238	359	L15	L25	L40	L75
	E	L15	L15	L20	L30	L50	L75	37	54	L15	L25	L40	L75
	F	L15	L15	L20	L30	L50	L75	213	315	L15	L25	L40	L75
20. Celgar Pulp (Power Consolidated) Arrow Lake Upstream	A	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	B	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
	C	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
Celgar Pulp (Power Consolidaed) Columbia River Downstream	D	L15	L15	L20	L30	L50	L75	642	642	L15	L25	L40	L75
	E	L15	L15	L20	L30	L50	L75	298	330	L15	L25	L40	L75
	F	L15	L15	L20	L30	L50	L75	100	125	L15	L25	L40	L75
21. Proctor & Gamble Pulp (Grande Prairie) Wapiti River Upstream	A	L2	L2	L2	L2	L5	L16	L2	L2	L2	L2	L2	L16
	(AA)[6]	(L1)	(L1)	(L2)	(L4)	(L5)	(L20)	(NA)[7]	(1)	(L1)	(L1)	(L2)	(L4)
Proctor & Gamble Pulp Wapiti River Downstream	B	L6	5	L2	6	L5	L20	36	54	L2	L1	L2	L6
	(BB)[8]	(L5)	(5)	(L2)	(L5)	(L8)	(L9)	(32)	(L50)	(L3)	(L1)	(L1)	(L2)

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection
(6) Duplicate samples (split on the field) results in brackets
(7) NA denotes results unavailable
(8) Duplicate samples (split in the laboratory) results in brackets

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
22. Weldwood of Canada (Hinton) Athabasca River Upstream	A	L1	L1	L1	L1	22	7	L1	L1	L1	L1	L1	L3
	(AA)[9]	(L1)	(L1)	(L1)	(L1)	(59)	(180)	(L1)	(L1)	(L1)	(L1)	(L1)	(L5)
Weldwood Of Canada (Hinton) Athabasca River Downstream	B	L2[2]	L2	L2	L4	15	130	7	7	L2	2	5	7
	(BB)[9]	(L2)	(L2)	(L3)	(L5)	(9)	(75)	(2)	(2)	(L2)	(L2)	(L3)	(L4)
Weldwood of Canada Athabasca Lake Downstream	C	L5	L5	L6	L32	L49	L118	L5	L5	L6	L32	L49	L118
23. Weyerhaeuser Canada (Prince Albert) North Saskatchewan River Downstream	A	L2	L2	L2	L2	20	180	L2	L2	L2	L2	L3	L4
24. Manfor (REPAP) (The Pas) Saskatchewan River Upstream	A	L15	L15	37	32	L50	265	L10	L10	L15	L25	L40	L75
Manfor Saskatchewan River Downstream	B[10]	L15	L15	L20	L30	L50	L75	L10	L10	L15	L25	L40	L75
25. Domtar Inc. (Cornwall) St. Lawrence River Upstream	A[11]	L20	L20	L61	L62	L140	168	L20	L20	L61	L62	L140	L101
Domtar Inc. (Cornwall)	B	L13	L13	L5	L52	120	827	L13	L13	120	800	401	920
St. Lawrence River Downstream	C	L12	L12	L120	L97	813	3468	L12	L12	114[12]	276	584	621

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection
(9) Duplicate samples (split in laboratory) results in brackets
(10) Recoveries were very low, probably a matrix related problem
(11) High detection limit value due to chemical interference
(12) Value lower than quantitation criteria: a peak was detected at 114 pg/g

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
26. Canadian Pacific Forest Products (Dryden) Wabigoon Lake Upstream	A	L20[2]	L4	L8	L4	24	83	L10	12	L5	L3	5	11
Canadian Pacific Forest (Dryden) Wabigoon River Downstream	B[13]	L30	L20	L20	L10	110	380	280	340	L20	12	21	L40
	C[13]	66*	53	L60	11	120	320	1200	1400	44	L30	32	52
	D[13]	L10	L4	L50	9	96	160	72	100	11	36	21	24
	E[13]	L30	L30	L10	L5	77	100	120	190	L20	240	240	580
27. E.B. Eddy Forest Prod. (Espanola Mill Division) Espanola Spanish River Upstream	A	L2	L2	L2	L46	L21	40	L2	L2	L2	L46	L21	L32
E.B. Eddy Forest Prod. Spanish River Downstream	B	L9	L9	L5	L41	L14	133	58	156	L5	L41	L14	L22
	C	L2	L2	L2	L38	L18	189	31	41	L2	L38	L18	L31
28. Boise Cascade Canada (Fort Frances) Rainy Lake Upstream	A	L3	NA[14]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	B	L1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Boise Cascade Canada (Fort Frances) Rainy River Lake of the Woods Downstream	C	L4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	D	L9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	E	8	NA	NA	NA	NA	780	NA	NA	NA	NA	NA	130
	F	L1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection
(13) High detection limit value due to chemical interference
(14) Non available results - analytical work by USEPA laboratory
* Differences between total T_4CDD and 2,3,7,8-T_4CDD due to intralaboratory analytical variation

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
29. James River Marathon Lake Superior Downstream	A	L1[2]	L1	L1	L2	L4	L9	6	9	L1	L1	L2	L9
	B	L1	L1	L1	L4	L4	L4	L1	L1	L1	L2	L2	L4
	C	L2	L2	L2	L3	L10	28	3	3	L2	L1	L2	L5
	D	L1	L1	L2	L3	L4	L4	3	3	L2	L1	L2	L4
	E	L1	L1	L4	22	30	150	230	570	210	180	43	47
	F	L1	L1	L1	49	890	1700	16	26	1	3	25	30
30. Domtar (Container Board Division) Red Rock Superior Lake Downstream (1986)	A	L4	13	L5	550	10000	70000	12	36	L5	190	1100	1600
	B	L6	L6	L10	130	9700	77000	L6	29	L10	L10	310	930
	C	L5	L5	L7	760	8400	61000	20	58	L7	190	1000	1400
Domtar Red Rock Superior Lake Upstream (1989)	D	L12	L12	L38	L36	L38	138	L12	L12	L38	L36	L38	L17
Domtar Red Rock Superior Lake Downstream (1989)	E	L10	L10	L20	L25	L20	18	L10	L10	L20	L25	L20	L14
	F	L18	L18	L23	L40	962	3995	L18	L18	L23	L40	207	468
31. Fraser Inc. Thorold Old Welland Canal Downstream	A[15]	L24	L24	L85	L84	L16	323	L24	L24	L85	L84	L16	L6
32. Kimberlay Clark (Terrace Bay Division) Superior Lake Downstream	A	L7	2	L1	L1	4	14	15	23	L1	L1	L1	L3
	B	61*	35	L40	L20	230	660	430	740	L30	18	78	160
	C	67*	38	L40	48	270	710	730	880	52	19	80	150

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection
(15) High detection limit value due to chemical interference
* Differences between total T_4CDD and 2,3,7,8-T_4CDD due to intralaboratory analytical variation

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
33. C.P. Forest Products (Thunder Bay Division) Thunder Bay Kaministiquia River Upstream	A	L7[2]	L7	L30	L31	L51	L61	L7	L7	L30	L31	L51	L61
C.P. Forest Products Kaministiquia River Downstream	B	L7	L7	L4	L30	L40	L20	L7	L7	L4	L30	L40	L20
	C	L4	14	L17	L52	L68	79	L4	L4	L17	L52	L68	L11
34. Malette Kraft Pulp & Paper Smooth Rock Falls Mattagami River Upstream	A	L11	L11	L8	L41	L80	33	L11	L11	L8	L41	L80	L15
Malette Kraft Pulp & Paper Mattagami River Downstream	B	L3	L3	L12	L30	L12	L20	L3	L3	L12	L30	L12	L20
	C	L11	L11	L23	L42	L16	L12	L11	L11	L23	L42	L16	L12
35. Tembec Inc. Ottawa River Downstream	A	L1	L1	L1	14	100	270	3	3	L1	L2	16	16
36. Cascades Inc. (Jonquière) Saguenay River Downstream	A	L1	L1	L1	L1	25	7	L1	L1	L1	L1	7	L4
37. Les Produits Forestiers Canadien Pacifique Ltée (La Tuque) St-Maurice River Downstream	A	5	5	L2	52	160	590	46	77	L2	3	21	50
38. Produits Des Pâtes et Papiers Domtar (Lebel-sur-Quévillon) Quévillon R. Downstream	A	43*	31	L4	28	39	76	57	95	84	42	23	22

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection

* Differences between total T_4CDD and 2,3,7,8-T_4CDD due to intralaboratory analytical variation

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
39. Stone Consolidated Inc. (Division Pontiac) Portage-du-Fort Ottawa River Downstream	A	L8[2]	L6	L7	51	98	210	8	30	5	L5	27	30
40. Donohue St-Félicien Inc. (St-Félicien) Mistassini River Downstream	A	L2	2	L2	19	68	72	5	8	L2	5	37	20
	(AA)[16]	(L10)	(2)	(L3)	(L2)	(L9)	(L40)	(7)	(6)	(L1)	(11)	(25)	(L20)
	(AAA)[16]	(L3)	(L3)	(L9)	(8)	(26)	(410)	(13)	(13)	(L9)	(L5)	(57)	(46)
41. Industries James MacLaren Inc. (Thurso) Ottawa River Downstream	A	L9	L1	L4	L20	52	170	5	9	L1	8	14	22
42. Stone Consolidated Inc. (Trois-Rivières) Saint-Maurice R. Upstream	A	L1	L1	L2	20	80	350	25	36	L2	L2	45	160
Stone Consolidated Inc. St-Maurice River Downstream	B	L9	L9	L62	L9	L54	L51	L9	L9	L62	L9	L54	L51
	C[17]	L18	L18	L103	L65	L77	103	L18	L18	L103	L65	L77	L78
Stone Consolidated Inc. St-Lawrence River Downstream	D[17]	L17	L17	L55	L62	L82	L136	L17	L17	L55	L62	L82	L136
43. Domtar (Windsor) Saint-François River Downstream	A	L6	L3	L2	18	130	360	14	23	4	17	49	66

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection
(16) Duplicate sample (split on the field) results in brackets
(17) High detection limit value due to chemical interference

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
44. St. Anne-Nackawic (Nackawic) St. John River Upstream	A	L2[2]	L2	L2	40	80	320	L2	L2	L2	L2	9	L9
	B	L5	L1	L1	14	59	170	L6	3	2	L2	12	21
St. Anne-Nackawic St. John River Downstream	C	L2	L2	18	110	1100	2600	18	27	L2	27	160	210
	D	L20	L3	L3	62	610	1900	10	15	10	77	270	260
45. Miramichi Pulp & Paper (Newcastle) Miramichi River[18] Upstream	A	L5	L5	L7	L7	250	960	91	150	L6	22	78	61
Miramichi Pulp & Paper Miramichi River[18] Downstream	B	L3	L3	10	6	71	490	34	47	4	10	43	68
	C	L10	4	L1	8	58	140	20	34	L3	4	14	18
46. Irving Pulp & Paper (St. John) St. John River[18] Upstream	A	L1	L1	L1	7	33	120	L1	L1	L1	L1	10	23
Irving Pulp & Paper St. John River[18] Downstream	B	L1	3	L1	9	54	89	L1	11	L1	L1	11	11
47. Atholville Pulp Restigouche River[18] Upstream	A	L3	L3	L3	L6	9	47	L2	L2	L2	L2	L3	L4
Atholville Pulp Restigouche River[18] Downstream	B	L6	L6	L7	L8	27	150	L4	L4	L5	L6	16	L12

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection
(18) Estuary/Tidal Section

Appendix F.1. (continued)

Mill and Sampling Location	Specific Site	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8, T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
48. Fraser Inc. (Edmundston) St. John River Upstream	A	L1[2]	L1	L2	L3	20	40	L1	L1	L1	L1	L2	L20
Fraser Inc. St. John River Downstream	B	L1	L1	L2	19	170	540	5	13	L2	L2	L2	27
49. Scott Maritimes (New Glasgow) Northumberland Strait Coastal	A	L9	L1	L2	L2	L4	12	6	4	L1	L1	L1	L10
	B	L1	L1	L1	L1	L2	L20	1	1	L1	L1	L1	L5
50. Stora Forest Products (Port Hawkesbury) Strait of Canso Coastal	A	L2	L2	L2	200	2200	3700	L2	L2	L2	71	150	230
	B	L4	L4	L9	L20	L20	L30	210	360	L9	L10	L10	L30
51. Western Pulp Partnership Port Alice, British Columbia Coastal	A	L4	100	36	330	280	1000	64	120	100	180	450	180
	B	L4	31	9	120	120	560	13	13	44	140	590	120

(2) L denotes values below detection limit: numbers following "L" represent the limit of detection

APPENDIX F-2

ANALYSIS OF INDIVIDUAL PCDD AND PCDF ISOMERS - CONCENTRATION IN PG/G (DRY WEIGHT)

APPENDIX F.2

Analysis of Individual PCDD and PCDF Isomers - Concentration in ppt (pg/g dry wt.)

Individual Isomers and Total	Sampling Location 1 A	1 B	1 C	3 A	3 B	14 A	14 B
Dioxins							
T4CDD-total	71	L1	L1	L3	7	L4	25
2378	L3	L1	L1	L3	2	L4	25
P5CDD-total	22	L1	L1	28	28	L5	92
12378	L3	L1	L1	L3	L2	L5	20
H6CDD-total	330	9	20	620	400	790	2800
123478	L3	L2	L1	L4	L2	L5	L3
123678	57	L2	L1	110	64	120	420
123789	17	L2	L1	48	34	48	180
H7CDD-total	400	6	7	230	78	130	410
1234678	210	6	7	130	38	81	180
O8CDD-total	2600	38	30	910	220	280	930
Furans							
T4CDF-total	31	L1	3	590	740	490	1400
2378	22	L1	3	360	430	340	860
P5CDF-total	63	L1	L1	96	56	L3	L2
12378	L2	L1	L1	7	19	L3	L2
23478	L2	L1	L1	17	25	L3	L2
H6CDF-total	300	4	L1	360	35	13	70
123478	L3	L2	L1	7	L2	L4	L3
123678	L3	L2	L1	L3	L2	L4	L3
123789	L3	L2	L1	48	28	L4	56
234678	L3	L2	L1	L7	L2	13	14
H7CDF-total	570	14	L2	540	29	19	45
1234678	200	4	L2	220	14	L5	8
1234789	L4	L3	L2	L4	5	19	10
O8CDF-total	230	8	L4	190	20	29	21

Analysis of Individual PCDD and PCDF Isomers,
Concentration in ppt (pg/g dry wt.)

Individual Isomers and Total	Sampling Location 21 A	21 AA	21 B	21 BB	22 A	22 AA	22 B	22 B	23
Dioxins									
T4CDD-total	L2	L1	5	5	L1	L1	L2	L2	L2
2378	L2	L1	L6	L5	L1	L1	L2	L2	L2
P5CDD-total	L2	L2	L2	L2	L1	L1	L2	L3	L2
12378	L2	NA	L9	L9	L1	L1	L2	L3	L2
H6CDD-total	L2	L4	6	L5	L1	L1	L4	L5	L2
123478	L2	NA	L20	L20	L1	L1	L4	L5	L2
123678	NA	NA	L20	L20	NA	NA	L4	L5	L2
123789	NA	NA	L20	L20	NA	NA	L4	L5	L2
H7CDD-total	L5	L5	L5	L8	22	59	15	9	20
1234678	L5	NA	NA	NA	11	22	8	9	13
O8CDD-total	L16	L20	L20	L9	7	180	130	75	180
Furans									
T4CDF-total	L2	1	54	50	L1	L1	7	2	L2
2378	L2	NA	36	32	L1	L1	7	2	L2
P5CDF-total	L2	L1	L2	L3	L1	L1	L2	L2	L2
12378	L2	NA	L2	L3	L1	L1	L2	L2	L2
23478	L2	NA	L6	L10	L1	L1	L2	L2	L2
H6CDF-total	L2	L1	L1	L1	L1	L1	2	L2	L2
123478	NA	NA	L7	L6	NA	NA	2	L2	L2
123678	NA	NA	L8	L7	NA	NA	L2	L2	L2
123789	NA	NA	L30	L30	NA	NA	L2	L2	L2
234678	L2	NA	L8	L9	NA	NA	L2	L2	L2
					L1	L1	L2	L2	
H7CDF-total	L2	L2	L2	L1	L1	L1	5	L3	L3
1234678	L2	NA	NA	NA	L1	L1	5	L3	L3
1234789	NA	NA	NA	NA	NA	NA	L2	L3	L3
O8CDF-total	L16	L4	L6	L2	L3	L5	7	L4	L4

Analysis of Individual PCDD and PCDF Isomers, Concentration in ppt (pg/g dry wt.)

Individual Isomers and Total	Sampling Location 26 A	B	C	D	E
Dioxins					
T4CDD-total	L4	L20	53*	L4	L30
2378	L20	L30	66	L10	L30
P5CDD-total	L8	L20	L60	L50	L10
12378	L20	L30	L20	L30	L20
H6CDD-total	L4	9	11	9	L5
123478	L60	L40	L30	L40	L30
123678	L80	L50	L30	L50	L40
123789	L90	L50	L30	L60	L40
H7CDD-total	24	110	120	96	77
1234678	NA	NA	NA	NA	NA
O8CDD-total	83	380	320	160	100
Furans					
T4CDF-total	12	340	1400	100	190
2378	L10	280	1200	72	120
P5CDF-total	L5	L20	44	11	L20
12378	L20	L10	L10	L7	L10
23478	L30	L20	L30	L20	L9
H6CDF-total	L3	12	L30	36	240
123478	L30	L30	L20	L30	L30
123678	L30	L30	L10	L30	L30
123789	L200	L90	L100	L100	L90
234678	L40	L30	L30	L30	L30
H7CDF-total	5	21	32	21	240
1234678	NA	NA	NA	NA	NA
1234789	NA	NA	NA	NA	NA
O8CDF-total	11	L40	52	24	580

(1) 2,3,7,8 T_4CDD value is higher than total T_4CDD: Differences due to intralaboratory variation

Analysis of Individual PCDD and PCDF Isomers, Concentration in ppt (pg/g dry wt.)

Individual Isomers And Total	Sampling Location 29 A	B	C	D	E	F	30 A	B	C
Dioxins									
T4CDD-total	L1	L1	L2	L1	L1	L1	13	L6	L5
2378	L1	L1	L2	L1	L1	L1	L4	L6	L5
P5CDD-total	L1	L1	L2	L2	L4	L1	L5	L10	L7
12378	L1	L1	L2	L2	L4	L1	L5	L10	L7
H6CDD-total	L2	L4	L3	L3	22	49	550	130	760
123478	L2	L4	L3	L3	L7	7	140	41	140
123678	NA	NA	NA	NA	NA	NA	NA	NA	NA
123789	NA	NA	NA	NA	NA	NA	NA	NA	NA
H7CDD-total	L4	L4	10	L4	30	890	10000	9700	8400
1234678	L4	L4	10	L4	17	720	5700	7300	5200
O8CDD-total	L9	L4	28	L4	150	1700	70000	77000	61000
Furans									
T4CDF-total	9	L1	3	3	570	26	36	29	58
2378	6	L1	L3	3	230	16	12	L6	20
P5CDF-total	L1	L1	L2	L2	210	1	L5	L10	L7
12378	L1	L1	L2	L2	90	L1	L5	L10	L7
23478	L1	L1	L2	L2	120	L1	L5	L10	L7
H6CDF-total	L1	L2	L1	L1	180	3	190	L10	190
123478	NA	NA	NA	NA	NA	NA	NA	NA	NA
123678	NA	NA	NA	NA	NA	NA	NA	NA	NA
123789	NA	NA	NA	NA	NA	NA	NA	NA	NA
234678	L1	L2	L1	L1	90	L1	140	L10	150
H7CDF-total	L2	L2	L2	L2	43	25	1100	310	1000
1234678	L2	L2	L2	L2	27	9	250	L10	230
1234789	NA	NA	NA	NA	NA	NA	NA	NA	NA
O8CDF-total	L9	L4	L5	L4	47	30	1600	930	1400

Analysis of Individual PCDD and PCDF Isomers,
Concentration in ppt (pg/g dry wt.)

Individual Isomers and Total	Sampling Location 32 A	32 B	32 C	35A	36A	37A	38A
Dioxins							
T4CDD-total	2	35(1)	38(1)	L1	L1	5	31(1)
2378	L7	61	67	L1	L1	5	43
P5CDD-total	L1	L40	L40	L1	L1	L2	L4
12378	L9	L40	L50	L1	L1	L2	L20
H6CDD-total	L1	L20	48	14	L1	52	28
123478	L20	L80	L100	L2	L1	12	L40
123678	L20	L100	L100	NA	NA	NA	L40
123789	L20	L100	L100	NA	NA	NA	L40
H7CDD-total	4	230	270	100	25	160	39
1234678	NA	NA	NA	58	17	NA	NA
O8CDD-total	14	660	710	270	7	590	76
Furans							
T4CDF-total	23	740	880	3	L1	77	95
2378	15	430	730	3	L1	46	57
P5CDF-total	L1	L30	52	L1	L1	L2	84
12378	L4	L20	L30	L1	L1	L2	27
23478	L7	L50	L30	L1	L1	L2	L40
H6CDF-total	L1	18	19	L2	L1	3	42
123478	L7	L30	L30	NA	NA	NA	L20
123678	L9	L30	L30	NA	NA	NA	L20
123789	L40	L80	L200	NA	NA	NA	L80
234678	L10	L20	L60	L2	L1	L2	L30
H7CDF-total	L1	78	80	16	7	21	23
1234678	NA	NA	NA	11	2	7	NA
1234789	NA	NA	NA	NA	NA	NA	NA
O8CDF-total	L3	160	150	16	L4	50	22

(1) 2,3,7,8 T_4CDD value is higher than total T_rCDD:
Differences due to intralaboratory variation

Analysis of Individual PCDD and PCDF Isomers,
Concentration in ppt (pg/g dry wt.)

Individual Isomers and Total	Sampling Location										
	39A	40			41A	42A	43A	44			
		A	AA1	AA2				A	AA	B	BB
Dioxins											
T4CDD-total	L6	L2	2	L3	L1	L1	L3	L2	L1	L2	L3
2378	L8	L10	L2	L3	L9	L1	L6	L2	L5	L2	L20
P5CDD-total	L7	2	L2	L9	L4	L2	L2	L2	L1	18	L3
12378	L20	L8	L2	L9	L10	L2	L6	L2	L10	L2	L30
H6CDD-total	51	L3	19	8	L20	20	18	40	14	110	62
123478	L60	L10	L2	L2	L40	L2	L10	6	L30	25	L50
123678	L70	L20	NA	4	L40	NA	L20	NA	L40	NA	L60
123789	L60	L20	NA	L12	L40	NA	L10	NA	L40	NA	L50
H7CDD-total	98	L9	68	26	52	80	130	80	59	1100	610
1234678	NA	NA	49	15	NA	55	NA	61	NA	890	NA
O8CDD-total	210	L40	72	410	170	350	360	320	170	2600	1900
Furans											
T4CDF-total	30	6	8	13	9	36	23	L2	3	27	15
2378	8	7	5	13	5	25	14	L2	L6	18	10
P5CDF-total	5	L1	L2	L9	L1	L2	4	L2	2	L2	L10
12378	L9	L3	L2	L9	L6	L2	L3	L2	L4	L2	L30
23478	L9	L7	L2	L9	L10	L2	L4	L2	L7	L2	L20
H6CDF-total	L5	11	5	L5	8	L2	17	L2	L2	26	77
123478	L20	L7	NA	L5	L20	NA	L5	NA	L6	NA	L20
123678	L20	L8	NA	L5	L20	NA	L6	NA	L7	NA	L20
123789	L60	L30	NA	L5	L60	NA	L20	NA	L60	NA	L100
234678	L20	L9	L2	L5	L20	L2	L6	L2	L20	L2	L30
H7CDF-total	27	25	37	L57	14	45	49	9	12	160	270
1234678	NA	NA	27	30	NA	25	NA	9	NA	40	NA
1234789	NA	NA	NA	L6	NA	NA	NA	NA	NA	NA	NA
O8CDF-total	30	L20	20	46	22	160	66	L9	21	210	260

NA - Results on these isomers were not available/not analysed.

Analysis of Individual PCDD and PCDF Isomers, Concentration in ppt (pg/g dry wt.)

Individual Isomers and Total	Sampling Location 45 A	45 B	45 BB	46 A	46 B	47 A	47 B
Dioxins							
T4CDD-total	L5	L3	4	L1	3	L3	L6
2378	L5	L3	L10	L1	L1	L3	L6
P5CDD-total	L7	10	L1	L1	L1	L3	L7
12378	L7	L3	L6	L1	L1	L3	L7
H6CDD-total	L7	6	8	7	9	L6	L8
123478	L7	L3	L20	L1	L1	L6	L8
123678	L7	L3	L20	NA	NA	L6	L8
123789	L7	L3	L20	NA	NA	L6	L8
H7CDD-total	250	71	58	33	54	9	27
1234678	130	35	NA	13	19	9	18
O8CDD-total	960	490	140	20	89	47	150
Furans							
T4CDF-total	150	47	34	L1	11	L2	L4
2378	91	34	20	L1	L1	L2	L4
P5CDF-total	L6	4	L3	L1	L1	L2	L5
12378	L6	L2	L3	L1	L1	L2	L5
23478	L6	4	L6	L1	L1	L2	L5
H6CDF-total	22	10	4	L1	L1	L2	L6
123478	L5	L2	L8	NA	NA	L2	L6
123678	L5	L2	L10	NA	NA	L2	L6
123789	8	L2	L30	NA	NA	L2	L6
234678	6	L2	L9	L1	L1	L2	L6
H7CDF-total	78	43	14	10	11	L3	16
1234678	30	15	NA	6	6	L3	16
1234789	L14	L4	NA	NA	NA	L3	L11
O8CDF-total	61	68	18	23	11	L4	L12

Analysis of Individual PCDD and PCDF Isomers,
Concentration in ppt (pg/g dry wt.)

Individual Isomers and Total	Sampling Location 48 A	48 B	49 A	49 B	50 A	50 B	51 A	51 B
Dioxins								
T4CDD-total	L1	L1	L1	L1	L2	L4	100	31
2378	L1	L1	L9	NA	L2	L4	L4	L4
P5CDD-total	12	L2	L2	L1	L2	L9	36	19
12378	NA	L2	L7	NA	L2	L9	L5	L5
H6CDD-total	13	19	L2	L1	200	L20	330	120
123478	NA	L2	L30	NA	16	L20	L6	L5
123678	NA	NA	L40	NA	NA	NA	46	11
123789	NA	NA	L30	NA	NA	NA	16	L5
H7CDD-total	20	170	L4	L2	2200	L20	280	120
1234678	NA	110	NA	NA	490	L20	160	65
O8CDD-total	40	540	12	L20	3700	L30	1000	560
Furans								
T4CDF-total	L1	13	4	1	L2	360	120	13
2378	L1	5	6	NA	L2	210	64	13
P5CDF-total	L1	L2	L1	L1	L2	L9	100	44
12378	NA	L2	L6	NA	L2	L9	L4	L3
23478	NA	L2	L7	NA	L2	L9	7	L3
H6CDF-total	L1	L2	L1	L1	71	L10	180	140
123478	NA	NA	L7	NA	NA	NA	L5	5
123678	NA	NA	L8	NA	NA	NA	L5	L4
123789	NA	NA	L40	NA	NA	NA	11	L4
234678	NA	L2	L10	NA	L2	L10	L5	L4
H7CDF-total	L2	L2	L1	L1	150	L10	450	590
1234678	NA	L2	NA	NA	60	L10	290	390
1234789	NA	NA	NA	NA	NA	NA	L5	L5
O8CDF-total	L20	27	L10	L5	230	L30	180	120

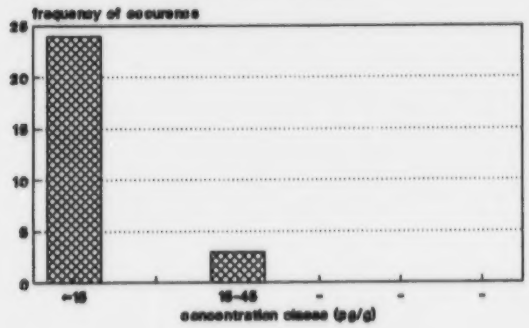
APPENDIX G

FREQUENCY DISTRIBUTION FOR DIOXIN AND FURAN CONCENTRATION CLASSES - COMPARISONS OF COASTAL AND DOWNSTREAM SAMPLING SITES

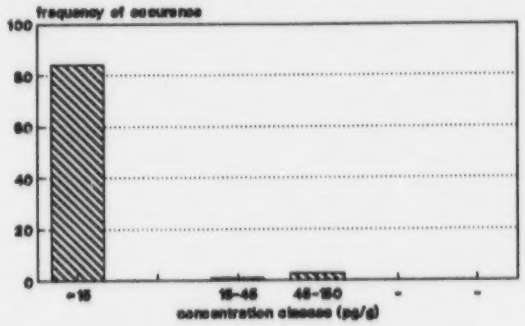
APPENDIX G-1

FREQUENCY DISTRIBUTION FOR DIOXIN CONCENTRATION CLASSES -
TETRA TO PENTACHLORINATED CONGENERS
COMPARISONS OF COASTAL AND DOWNSTREAM SAMPLING SITES

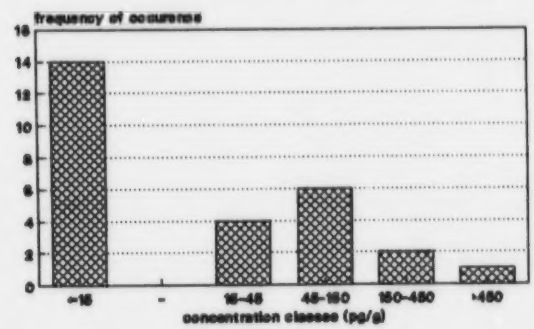
COASTAL SAMPLING SITE
2,3,7,8-T4CDD



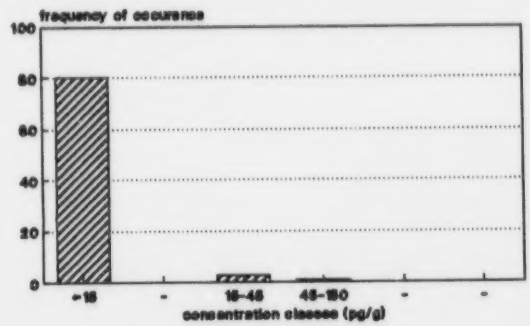
DOWNSTREAM SAMPLING SITE
2,3,7,8-T4CDD



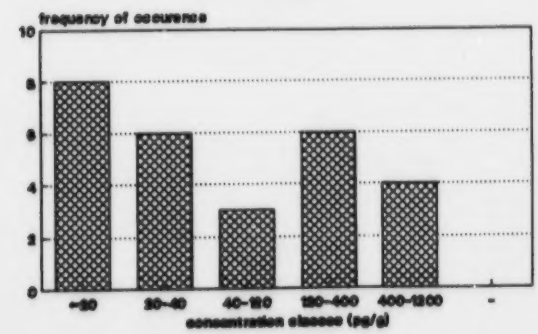
T4CDD



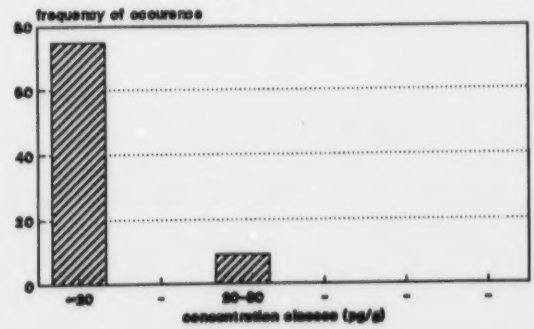
T4CDD



P5CDD



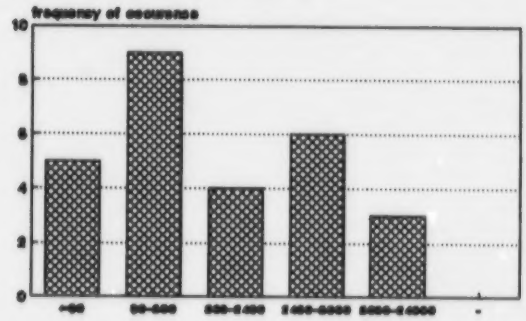
P5CDD



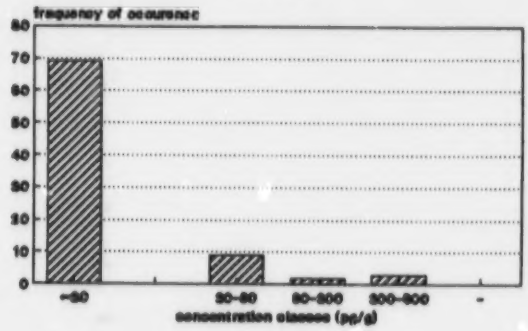
APPENDIX G-2

FREQUENCY DISTRIBUTION FOR DIOXIN CONCENTRATION CLASSES -
HEXA TO OCTACHLORINATED CONGENERS
COMPARISONS OF COASTAL AND DOWNSTREAM SAMPLING SITES

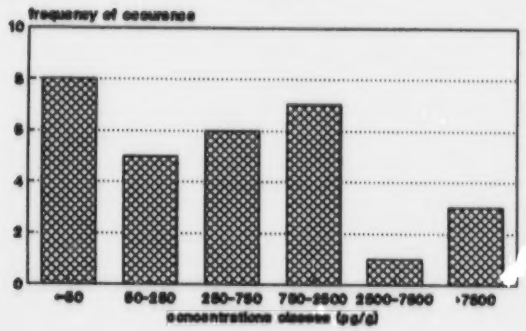
COASTAL SAMPLING SITES
H6CDD



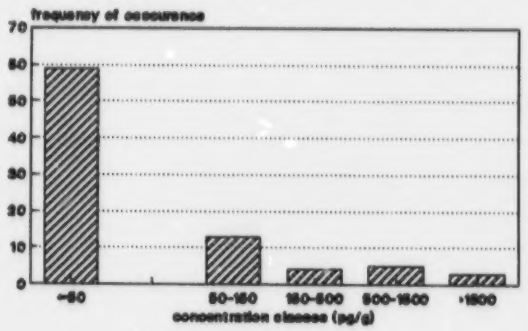
DOWNSTREAM SAMPLING SITE
H6CDD



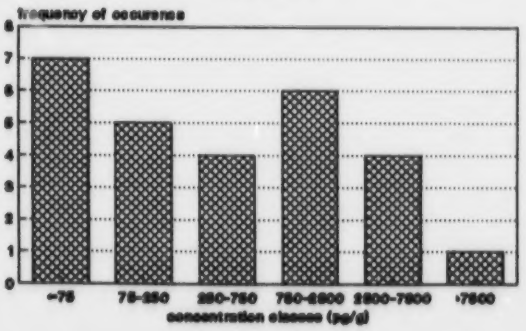
H7CDD



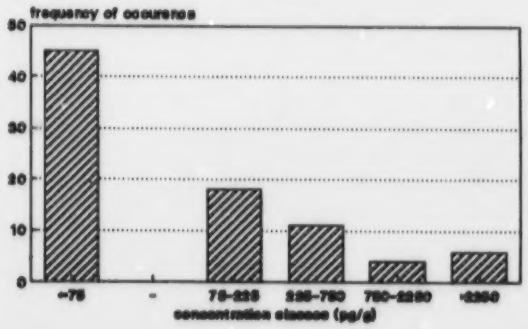
H7CDD



O8CDD



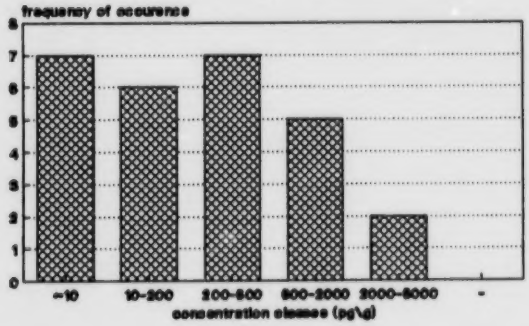
O8CDD



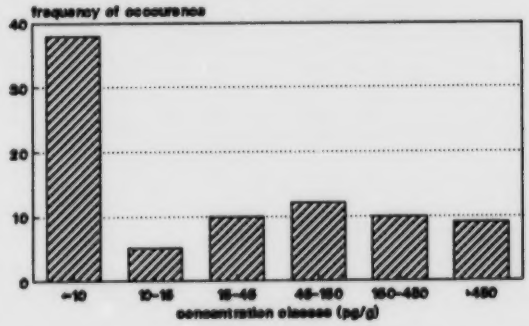
APPENDIX G-3

FREQUENCY DISTRIBUTION FOR FURAN CONCENTRATION CLASSES -
TETRA TO PENTACHLORINATED CONGENERS
COMPARISONS OF COASTAL AND DOWNSTREAM SAMPLING SITES

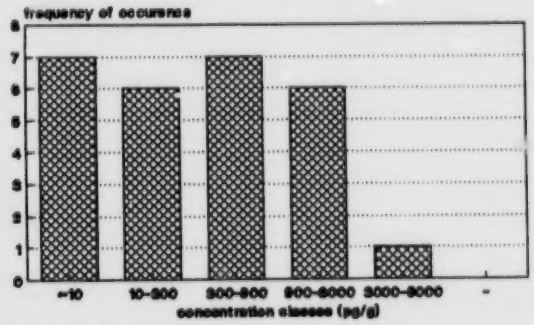
COASTAL SAMPLING SITES
2,3,7,8-T4CDF



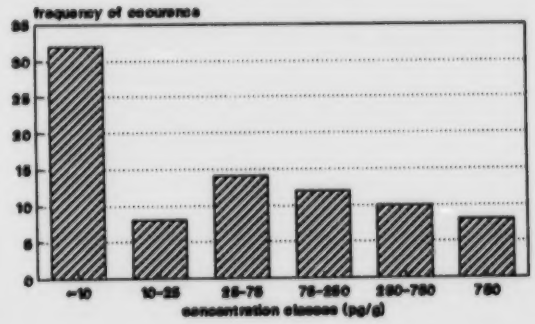
DOWNSTREAM SAMPLING SITE
2,3,7,8-T4CDF



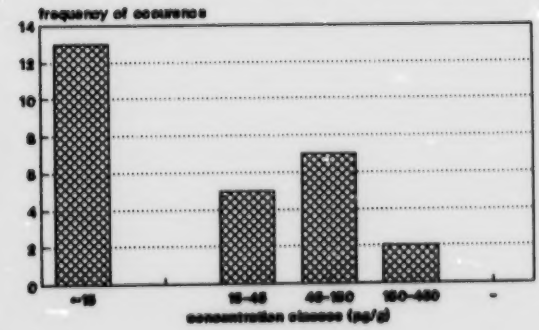
T4CDF



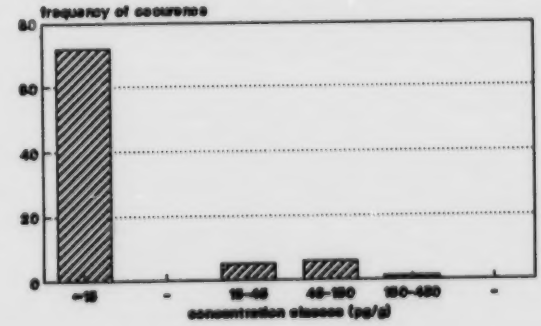
T4CDF



P5CDF



P5CDF

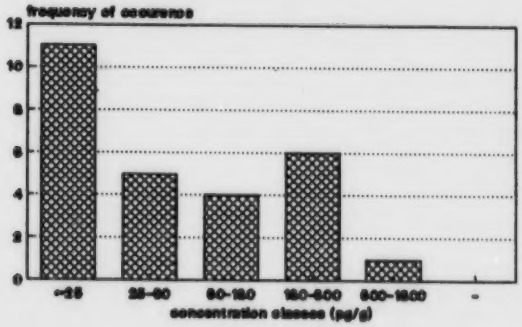


APPENDIX G- 4

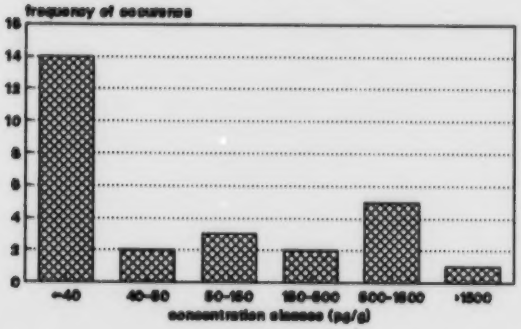
FREQUENCY DISTRIBUTION FOR FURAN CONCENTRATION CLASSES -
HEXA TO OCTACHLORINATED CONGENERS
COMPARISONS OF COASTAL AND DOWNSTREAM SAMPLING SITES

COASTAL SAMPLING SITES

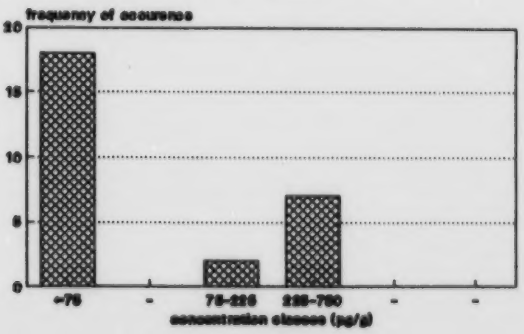
H6CDF



H7CDF

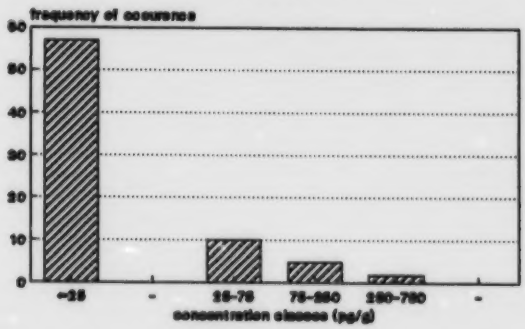


O8CDF

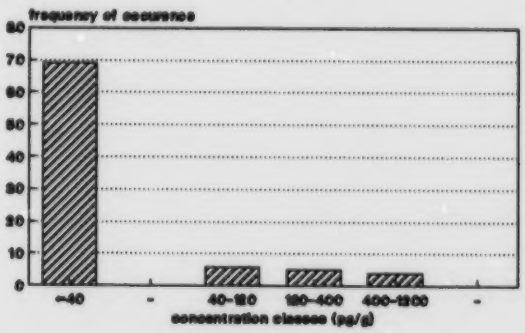


DOWNSTREAM SAMPLING SITE

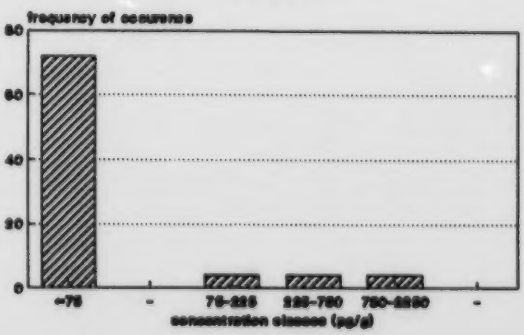
H6CDF



H7CDF



O8CDF



APPENDIX H
TOXICITY EQUIVALENTS OF 2,3,7,8-T_4CDD (PG/G) IN SEDIMENTS FROM COASTAL AND INLAND SITES

Appendix H-1. Procedure for Calculation of TEQs.

Appendix H-2. Relative Contribution to the TEQs of 2,3,7,8-T_4CDD - Coastal Sites.

Appendix H-3. Relative Contribution to the TEQs of 2,3,7,8-T_4CDD - Inland Sites.

APPENDIX H-1

PROCEDURE FOR CALCULATION OF TEQS

APPENDIX H

PROCEDURE FOR CALCULATION OF TEQs

As mentioned in section 4.1.2 (Treatment of Censored Data Set- page 14) the assessment of the data must take into consideration that analytical results were reported in different ways by the laboratories. To ensure that TEQ calculations are consistent, measurements less than NWQL limits of detection are replaced by fixed value equal about to half of the limit of detection.

Therefore, for TEQ calculation with measurements less than limit of quantitation, the following values are assigned:

2,3,7,8-T4CDD	(<=15 pg/g)	7.5 pg/g
P5CDD	(<=20 pg/g)	9.5 pg/g
H6CDD	(<=30 pg/g)	14.5 pg/g
H7CDD	(<=50 pg/g)	24.5 pg/g
O8CDD	(<=75 pg/g)	37.5 pg/g
2,3,7,8-T4CDF	(<=10 pg/g)	4.5 pg/g
P5CDF	(<=15 pg/g)	7.5 pg/g
H6CDF	(<=25 pg/g)	12.5 pg/g
H7CDF	(<=40 pg/g)	19.5 pg/g
O8CDF	(<=75 pg/g)	37.5 pg/g

(Decimal values are used here to make distinction betveen assigned values for TEQ calculation and measurements in Appendix F.1)

The four following examples were selected to show the procedure used to calculate the TEQs presented in this appendice and in the province summary figures (figures 6a to 6f).

APPENDIX H. PROCEDURE FOR TEQs CALCULATION
EXAMPLE SITE #3A

	DIOXIN (pg/g dry wt.)					FURAN (pg/g dry wt.)				
	2,3,7,8, T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8, T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
MEASUREMENT VALUES REPORTED IN APPENDIX F.1	L3	28	620	230	910	360	96	360	540	190
LIMIT OF DETECTION (1) (MMQL)	15	20	30	50	75	10	15	25	40	75
VALUE ASSIGNED OR RETAINED FOR (2) TEQs CALCULATION	7.5	28	620	230	910	360	96	360	540	190
TOXICITY EQUIVALENCY FACTOR (3) (TEF)	1	0.5	0.1	0.01	0.001	0.1	0.05	0.1	0.01	0.001
CONTRIBUTION TO TEQs (4)	7.5	14	62	2.3	0.91	36	4.8	36	5.4	.19

(1) See Section 4.1.2 (page 14) for justification
(2) When a measurement is less than detection limit, TEQs are calculated with an assigned value (equal to approximately half of the limit of detection).
(3) See Table 2 (page 15)
(4) Rounded Product of Assigned value (2) X TEF (3)

APPENDIX H. PROCEDURE FOR TEQs CALCULATION
EXAMPLE SITE #4A

	DIOXIN (pg/g dry wt.)					FURAN (pg/g dry wt.)				
	2,3,7,8, T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8, T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
MEASUREMENT VALUES REPORTED IN APPENDIX F.1	L15	L20	L30	L50	L75	L10	L15	L25	L40	L75
LIMIT OF DETECTION (1) (MMQL)	15	20	30	50	75	10	15	25	40	75
VALUE ASSIGNED OR RETAINED FOR (2) TEQs CALCULATION	7.5	9.5	14.5	24.5	37.5	4.5	7.5	12.5	19.5	37.5
TOXICITY EQUIVALENCY FACTOR (3) (TEF)	1	0.5	0.1	0.01	0.001	0.1	0.05	0.1	0.01	0.001
CONTRIBUTION TO TEQs (4)	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04

(1) See Section 4.1.2 (page 14) for justification
(2) When a measurement is less than detection limit, TEQs are calculated with an assigned value (equal to approximately half of the limit of detection).
(3) See Table 2 (page 15)
(4) Rounded Product of Assigned value (2) X TEF (3)

APPENDIX H. PROCEDURE FOR TEQs CALCULATION
EXAMPLE SITE #11A

	DIOXIN (pg/g dry wt.)					FURAN (pg/g dry wt.)				
	2,3,7,8, T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8, T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
MEASUREMENT VALUES REPORTED IN APPENDIX F.1	L3	L5	L6	L10	16	5	L3	L6	L6	L10
LIMIT OF DETECTION (1) (MMQL)	15	20	30	50	75	10	15	25	40	75
VALUE ASSIGNED OR RETAINED FOR (2) TEQs CALCULATION	7.5	9.5	14.5	24.5	37.5	4.5	7.5	12.5	19.5	37.5
TOXICITY EQUIVALENCY FACTOR (3) (TEF)	1	0.5	0.1	0.01	0.001	0.1	0.05	0.1	0.01	0.001
CONTRIBUTION TO TEQs (4)	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04

(1) See Section 4.1.2 (page 14) for justification
(2) When a measurement is less than detection limit, TEQs are calculated with an assigned value (equal to approximately half of the limit of detection).
(3) See Table 2 (page 15)
(4) Rounded Product of Assigned value (2) X TEF (3)

APPENDIX E. PROCEDURE FOR TEQs CALCULATION
EXAMPLE SITE #14A

	DIOXIN (pg/g dry wt.)					FURAN (pg/g dry wt.)				
	2,3,7,8, T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8, T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
MEASUREMENT VALUES REPORTED IN APPENDIX F.1	L4	L5	790	130	280	340	L3	13	19	29
LIMIT OF DETECTION (1) (MMQL)	15	20	30	50	75	10	15	25	40	75
VALUE ASSIGNED OR RETAINED FOR (2) TEQs CALCULATION	7.5	10	790	130	280	340	7.5	12.5	19.5	37.5
TOXICITY EQUIVALENCY FACTOR (3) (TEF)	1	0.5	0.1	0.01	0.001	0.1	0.05	0.1	0.01	0.001
CONTRIBUTION TO TEQs (4)	7.5	5	79	1.3	2.8	34	0.4	1.3	0.2	0.04

(1) See Section 4.1.2 (page 14) for justification
(2) When a measurement is less than detection limit, TEQs are calculated with an assigned value (equal to approximately half of the limit of detection).
(3) See Table 2 (page 15)
(4) Rounded Product of Assigned value (2) X TEF (3)

APPENDIX H-2

RELATIVE CONTRIBUTION TO THE TEQS OF 2,3,7,8-T_4CDD - COASTAL SITES

APPENDIX H

TEQ OF 2,3,7,8-T_4CDD (pg/g)

COASTAL SITES

SAMPLING SITES	Relative contribution (pg/g)										TOTAL TEQ (pg/g)
	2378-T_4CDD	P_5CDD	H_6CDD	H_7CDD	O_8CDD	2378-T_4CDF	P_5CDF	H_6CDF	H_7CDF	O_8CDF	
1A	7.5	11.0	33.0	4.0	2.60	2.2	3.2	30.0	5.7	0.23	99.4
1B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
1C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
2A	7.5	11.5	27.2	0.2	0.04	2.9	0.4	1.3	0.2	0.04	51.2
2B	7.5	259.5	994.6	21.3	4.06	72.6	3.3	29.3	5.4	0.39	1398.0
2C	7.5	141.5	325.0	8.5	1.19	47.8	2.0	5.4	0.6	0.04	539.5
3A	7.5	14.0	62.0	2.3	0.91	36.0	4.8	36.0	5.4	0.19	169.1
3B	7.5	14.0	40.0	0.8	0.22	43.0	2.8	3.5	0.2	0.04	112.0
5G	7.5	9.0	12.5	0.4	0.11	0.5	0.9	3.1	0.4	0.04	34.3
5H	14.0	117.5	98.2	4.8	0.93	1.4	11.8	5.2	0.4	0.09	254.2
5I	7.5	9.3	4.6	0.2	0.04	0.5	0.9	4.6	0.3	0.04	27.9
7A	7.5	33.5	76.0	20.5	1.99	2.5	8.1	178.4	23.2	0.68	352.3
7B	7.5	255.0	322.9	13.6	1.68	28.8	6.6	52.0	7.8	0.27	696.1
7C	7.5	66.0	118.4	3.0	0.25	16.5	0.4	1.3	0.5	0.04	213.7
8A	7.5	555.0	1021.3	34.3	8.02	32.6	4.8	30.5	4.6	0.38	1699.0
9A	17.0	96.0	516.1	7.2	0.49	87.5	0.4	6.8	1.6	0.04	733.1
9B	7.5	34.5	175.6	1.5	0.08	89.7	0.4	1.3	0.2	0.04	310.8
10A	7.5	182.0	623.0	23.3	2.96	98.3	2.0	36.4	7.3	0.24	982.9
14A	7.5	4.8	79.0	1.3	0.28	34.0	0.4	1.3	0.2	0.04	128.7
14B	25.0	46.0	280.0	4.1	0.93	86.0	0.4	7.0	0.5	0.04	449.9
17A	27.0	239.0	1643.2	15.3	0.72	200.5	5.7	10.1	1.0	0.04	2142.5
17B	7.5	73.0	453.8	5.0	0.23	317.9	1.4	1.3	0.2	0.04	860.3
17C	7.5	4.8	114.8	1.2	0.10	14.8	0.4	1.3	0.2	0.04	145.0
49A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
49B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
50A	7.5	4.8	20.0	22.0	3.70	0.5	0.4	7.1	1.5	0.23	67.6
50B	7.5	4.8	1.5	0.2	0.04	21.0	0.4	1.3	0.2	0.04	36.8
51A	7.5	18.0	33.0	2.8	1.00	6.4	5.0	18.0	4.5	0.18	96.0
51B	7.5	5.0	12.0	1.2	0.50	1.3	2.2	14.0	5.9	0.12	50.0

APPENDIX B-3

RELATIVE CONTRIBUTION TO THE TEQS OF 2,3,7,8-T_4CDD - INLAND SITES

APPENDIX H

TEQ OF 2,3,7,8-T_4CDD (pg/g)

INLAND SITES

SAMPLING SITES	Relative contribution (pg/g)										TOTAL TEQ (pg/g)
	2378-T_4CDD	P_5CDD	H_6CDD	H_7CDD	O_8CDD	2378-T_4CDF	P_5CDF	H_6CDF	H_7CDF	O_8CDF	
4A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
4B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
4C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
4D	7.5	4.8	1.5	0.2	0.04	316.8	0.4	1.3	0.2	0.04	332.6
4E	7.5	4.8	1.5	0.2	0.04	224.5	0.4	1.3	0.2	0.04	240.3
4F	7.5	4.8	1.5	0.2	0.04	6.9	0.4	1.3	0.2	0.04	22.7
5A	7.5	4.8	2.4	0.2	0.04	0.5	0.4	2.4	0.2	0.04	18.3
5B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
5C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
5D	7.5	4.8	2.1	0.2	0.04	0.5	0.4	2.1	0.2	0.04	17.8
5E	7.5	4.8	3.0	0.2	0.04	0.5	0.4	3.0	0.2	0.04	19.6
5F	7.5	10.5	47.0	0.2	0.04	0.5	1.1	3.4	0.2	0.04	70.4
6A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
6B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
6C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
6D	7.5	4.8	1.5	0.2	0.57	207.7	2.6	3.4	0.2	0.04	228.4
6E	7.5	4.8	1.5	0.2	0.10	98.2	0.4	1.3	0.2	0.04	114.1
6F	7.5	4.8	1.5	0.2	0.04	108.2	0.4	1.3	0.2	0.04	123.9
11A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
11B	7.5	4.8	1.5	0.2	0.04	27.4	0.4	1.3	0.2	0.04	43.2
11C	7.5	4.8	1.5	0.2	0.04	7.0	0.4	1.3	0.2	0.04	22.8
11D	7.5	4.8	1.5	0.2	0.04	4.5	0.4	1.3	0.2	0.04	20.3
12/13A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
12/13B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
12/13C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
12/13D	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
12/13E	7.5	4.8	1.5	0.2	0.04	5.1	0.4	1.3	0.2	0.04	20.9
12/13F	7.5	4.8	1.5	0.2	0.04	6.4	0.4	1.3	0.2	0.04	22.2
12/13G	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
15A	7.5	4.8	1.5	0.2	0.04	1.4	0.4	1.3	0.2	0.04	17.2
15B	7.5	4.8	1.5	0.2	0.04	19.5	0.4	1.3	0.2	0.04	35.3
15C	7.5	4.8	1.5	0.2	0.04	15.9	0.4	1.3	0.2	0.04	31.7
15D	7.5	4.8	1.5	0.2	0.04	12.0	0.4	1.3	0.2	0.04	27.8

APPENDIX H

TEQ OF 2,3,7,8-T_4CDD (pg/g)

INLAND SITES

SAMPLING SITES	Relative contribution (pg/g)										TOTAL TEQ (pg/g)
	2378-T_4CDD	P_5CDD	H_6CDD	H_7CDD	O_8CDD	2378-T_4CDF	P_5CDF	H_6CDF	H_7CDF	O_8CDF	
16A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
16B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
16C	7.5	4.8	1.5	0.2	0.04	221.7	0.4	1.3	0.2	0.04	237.5
16D	7.5	4.8	1.5	0.2	0.04	7.8	0.4	1.3	0.2	0.04	23.6
16E	7.5	4.8	1.5	0.2	0.04	2.7	0.4	1.3	0.2	0.04	18.5
16F	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
18A	7.5	14.0	1.5	0.2	0.09	0.5	0.4	1.3	0.2	0.04	25.6
18B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
18C	7.5	4.8	1.5	0.2	0.21	28.6	0.4	1.3	0.2	0.04	44.6
19A	7.5	4.8	1.5	0.2	0.04	13.4	0.4	1.3	0.2	0.04	29.2
19B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
19C	7.5	4.8	1.5	0.2	0.04	3.7	0.4	1.3	0.2	0.04	19.5
19D	7.5	4.8	1.5	0.2	0.04	23.8	0.4	1.3	0.2	0.04	39.6
19E	7.5	4.8	1.5	0.2	0.04	3.7	0.4	1.3	0.2	0.04	19.5
19F	7.5	4.8	1.5	0.2	0.04	21.3	0.4	1.3	0.2	0.04	37.1
20A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
20B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
20C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
20D	7.5	4.8	1.5	0.2	0.04	64.2	0.4	1.3	0.2	0.04	80.0
20E	7.5	4.8	1.5	0.2	0.04	29.8	0.4	1.3	0.2	0.04	45.6
20F	7.5	4.8	1.5	0.2	0.04	10.0	0.4	1.3	0.2	0.04	25.8
21A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
21B	7.5	4.8	1.5	0.2	0.04	3.6	0.4	1.3	0.2	0.04	19.4
22A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
22B	7.5	4.8	1.5	0.2	0.13	0.5	0.4	1.3	0.2	0.04	16.4
22C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
23A	7.5	4.8	1.5	0.2	0.18	0.5	0.4	1.3	0.2	0.04	16.4
24A	7.5	18.5	3.2	0.2	0.27	0.5	0.4	1.3	0.2	0.04	32.0
24B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
25A	10.0	15.3	3.1	0.7	0.17	1.0	1.5	3.1	0.7	0.05	35.6
25B	7.5	4.8	2.6	1.2	0.83	0.7	6.0	80.0	4.0	0.92	108.5
25C	7.5	30.0	4.9	8.1	3.47	0.6	5.7	27.6	5.8	0.62	94.3

APPENDIX H

TEQ OF 2,3,7,8-T_4CDD (pg/g)

INLAND SITES

SAMPLING SITES	Relative contribution (pg/g)										TOTAL TEQ (pg/g)
	2378-T_4CDD	P_5CDD	H_6CDD	H_7CDD	O_8CDD	2378-T_4CDF	P_5CDF	H_6CDF	H_7CDF	O_8CDF	
26A	10.0	4.8	1.5	0.2	0.08	0.5	0.4	1.3	0.2	0.04	18.8
26B	15.0	4.8	1.5	1.1	0.38	28.0	0.5	1.3	0.2	0.04	52.7
26C	66.0	15.0	1.5	1.2	0.32	120.0	2.2	1.5	0.2	0.04	207.9
26D	7.5	12.5	1.5	1.0	0.16	7.2	0.4	3.6	0.2	0.04	34.0
26E	15.0	4.8	1.5	0.8	0.10	12.0	0.5	24.0	2.4	0.58	61.6
27A	7.5	4.8	2.3	0.2	0.04	0.5	0.4	2.3	0.2	0.04	18.2
27B	7.5	4.8	2.1	0.2	0.13	5.8	0.4	2.1	0.2	0.04	23.1
27C	7.5	4.8	1.9	0.2	0.19	3.1	0.4	1.9	0.2	0.04	20.2
28A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
28B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
28C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
28D	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
28E	7.5	4.8	1.5	0.2	0.78	0.5	0.4	1.3	0.2	0.13	17.1
28F	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
29A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
29B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
29C	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
29D	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
29E	7.5	4.8	1.5	0.2	0.15	23.0	10.5	18.0	0.4	0.04	66.1
29F	7.5	4.8	4.9	8.9	1.70	1.6	0.4	1.3	0.2	0.04	31.2
30A	7.5	4.8	55.0	100.0	70.00	1.2	0.4	19.0	11.0	1.60	270.4
30B	7.5	4.8	13.0	97.0	77.00	0.5	0.4	1.3	3.1	0.93	205.4
30C	7.5	4.8	76.0	84.0	61.00	2.0	0.4	19.0	10.0	1.40	266.0
30D	7.5	9.5	1.8	0.2	0.14	0.6	1.0	1.8	0.2	0.04	22.8
30E	7.5	4.8	1.5	0.2	0.04	0.5	0.5	1.3	0.2	0.04	16.4
30F	9.0	5.8	2.0	9.6	4.00	0.9	0.6	2.0	2.1	0.47	36.4
31A	12.0	21.3	4.2	0.2	0.32	1.2	2.1	4.2	0.2	0.04	45.8
32A	7.5	4.8	1.5	0.2	0.04	1.5	0.4	1.3	0.2	0.04	17.3
32B	61.0	10.0	1.5	2.3	0.66	43.0	0.8	1.3	0.8	0.16	121.4
32C	67.0	10.0	4.8	2.7	0.71	73.0	2.6	1.3	0.8	0.15	163.0

APPENDIX H

TEQ OF 2,3,7,8-T_4CDD (pg/g)

INLAND SITES

SAMPLING SITES	Relative contribution (pg/g)										TOTAL TEQ (pg/g)
	2378-T_4CDD	P_5CDD	H_6CDD	H_7CDD	O_8CDD	2378-T_4CDF	P_5CDF	H_6CDF	H_7CDF	O_8CDF	
33A	7.5	7.5	1.6	0.3	0.04	0.5	0.8	1.6	0.3	0.04	19.9
33B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.5	0.2	0.04	16.5
33C	7.5	4.8	2.6	0.3	0.08	0.5	0.4	2.6	0.3	0.04	19.1
34A	7.5	4.8	2.1	0.4	0.04	0.6	0.4	2.1	0.4	0.04	18.2
34B	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.5	0.2	0.04	16.5
34C	7.5	5.8	2.1	0.2	0.04	0.6	0.6	2.1	0.2	0.04	19.1
35A	7.5	4.8	1.5	1.0	0.27	0.5	0.4	1.3	0.2	0.04	17.3
36A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
37A	7.5	4.8	5.2	1.6	0.59	4.6	0.4	1.3	0.2	0.04	26.1
38A	43.0	4.8	1.5	0.2	0.08	5.7	4.2	4.2	0.2	0.04	63.9
39A	7.5	4.8	5.1	1.0	0.21	0.5	0.4	1.3	0.2	0.04	20.8
40A	7.5	4.8	1.5	0.7	0.04	0.5	0.4	1.3	0.2	0.04	16.7
41A	7.5	4.8	1.5	0.5	0.17	0.5	0.4	1.3	0.2	0.04	16.7
42A	7.5	4.8	1.5	0.8	0.35	2.5	0.4	1.3	0.5	0.16	19.6
42B	7.5	15.5	1.5	0.3	0.04	0.5	1.6	1.3	0.3	0.04	28.3
42C	9.0	25.8	3.3	0.4	0.10	0.9	2.6	3.3	0.4	0.04	45.6
42D	8.5	13.8	3.1	0.4	0.07	0.9	1.4	3.1	0.4	0.07	31.6
43A	7.5	4.8	1.5	1.3	0.36	1.4	0.4	1.3	0.5	0.04	18.9
44A	7.5	4.8	4.0	0.8	0.32	0.5	0.4	1.3	0.2	0.04	19.7
44B	7.5	4.8	1.5	0.6	0.17	0.5	0.4	1.3	0.2	0.04	16.8
44C	7.5	4.8	11.0	11.0	2.60	1.8	0.4	2.7	1.6	0.21	43.5
44D	10.0	4.8	6.2	6.1	1.90	0.5	0.4	7.7	2.7	0.26	40.4
45A	7.5	4.8	1.5	2.5	0.96	9.1	0.4	1.3	0.8	0.04	28.7
45B	7.5	4.8	1.5	0.7	0.49	3.4	0.4	1.3	0.4	0.04	20.4
45C	7.5	4.8	1.5	0.6	0.14	2.0	0.4	1.3	0.2	0.04	18.3
46A	7.5	4.8	1.5	0.2	0.12	0.5	0.4	1.3	0.2	0.04	16.4
46B	7.5	4.8	1.5	0.5	0.09	0.5	0.4	1.3	0.2	0.04	16.6
47A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
47B	7.5	4.8	1.5	0.2	0.15	0.5	0.4	1.3	0.2	0.04	16.4
48A	7.5	4.8	1.5	0.2	0.04	0.5	0.4	1.3	0.2	0.04	16.3
48B	7.5	4.8	1.5	1.7	0.54	0.5	0.4	1.3	0.2	0.04	18.2

APPENDIX I
PARTICLE SIZE DISTRIBUTION AND ORGANIC CARBON CONTENT

APPENDIX I-1. Particle Size Distribution and Organic Carbon Content in Bottom Sediments.

APPENDIX I-2. Graphs of Particle Size Distribution (Proportion of Clay and Silt) and Organic Carbon Content in Sediments Collected in British Columbia (Coastal), British Columbia (Inland), Prairies, Ontario, Québec and Atlantic Provinces.

APPENDIX I-3. Relationship between PCDD/PCDF Concentrations and Sediment Characteristics (Percent of Clay, Fine and Organic Carbon Content) at Coastal and Downstream Inland Sites.

APPENDIX I-1

PARTICLE SIZE DISTRIBUTION AND ORGANIC CARBON CONTENT IN BOTTOM SEDIMENTS

Appendix I-1. PARTICLE SIZE DISTRIBUTION AND TOTAL ORGANIC CARBON CONTENT IN BOTTOM SEDIMENTS

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
1. Fletcher Challenge (Elk Falls Pulp Division) Strait of Georgia Coastal	A	9.50	NA	NA	NA	NA
	B	0.32	0.8	1.7	97.5	0.0
	C	0.17	1.2	3.1	90.2	5.4
2. Fletcher Challenge (Crofton Division) Strait of Georgia Coastal	A	0.47	3	10	82	5
	(AA)(3)	NA	NA	NA	NA	NA
	B(4)	5.81	9	41	50	0
	C(4)	8.20	5	56	39	0
3. Canadian Pacific Forest Prod. (Gold River) Coastal	A	7.01	1.3	6.0	62.9	29.8
	B	1.69	1.2	3.0	63.3	32.5
4. Weyerhaeuser Canada (Kamloops) Thompson River Upstream	A	0.7	5.4	13.3	73.1	8.2
	B	0.27	3.3	7.3	88.2	1.2
	C	0.37	4.8	25.4	67.9	1.9
Weyerhaeuser Canada (Kamloops) Thompson River Downstream	D	1.2	-	2.5*	97.1	0.4
	E	1.1	-	3.4*	96.1	0.5
	F	0.28	-	10.4*	86.6	0.0

(1) specific site number description are given in Table 1
(2) particle size categories are defined as follows: gravel = 2-64 mm, sand = 0.062-2 mm, silt = 0.004 - 0.062 mm, clay = <0.004 mm
(3) replicate sample
(4) Analysis were performed on a small sample size: representativeness of the results are not as certain

NA no analysis
* refers to % particle size of silt and clay combined

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
5. Eurocon Pulp & Paper (Kitimat) River Upstream	A	0.66	5.3	23.6	71.1	0.0
	B	0.77	7.0	36.9	55.9	0.2
	C	0.39	4.2	11.3	84.3	0.2
Eurocan P&P Kitimat River Downstream	D	0.55	5.3	31.1	63.6	0.0
	E	0.25	5.4	16.9	77.6	0.1
	F	1.86	12.0	62.6	25.4	0.0
Eurocan P&P Kitimat Arm Coastal	G	.06	4	74	22.0	0.0
	H	1.39	3	50	46.3	0.7
	I	4.75	0	0.4	99.0	0.6
6. Fletcher Challenge (MacKenzie Pulp Division) Tudyah Lake Upstream	A	0.42	3.2	4.2	91.6	1.0
	B	0.4	4.3	8.6	86.7	0.4
	C	0.51	3.9	5.4	90.4	0.3
Fletcher Challenge (MacKenzie Pulp Division) Williston Lake Downstream	D	10.6	20.0	51.8	27.4	0.8
	E	5.8	19.7	77.4	2.9	0.0
	F	4.4	21.9	69.2	8.9	0.0
7. MacMillan Bloedel (Harmac Pulp Division) Strait of Georgia Coastal	A	4.65	2.0	11.0	69.0	18.0
	(AA)(3)	NA	NA	NA	NA	NA
	B	NA	NA	NA	NA	NA
	C	NA	NA	NA	NA	NA
8. MacMillan Bloedel (Alberni Division) Alberni Inlet Coastal	A	NA	NA	NA	NA	NA

(3) Replicate sample

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
9. Canfor Port Mellon Pulp (Howe Sound) Coastal	A(4)	0.87	0.0	4.0	88.0	8.0
	B	0.35	0.0	3.0	92.0	5.0
10. MacMillan Bloedel (Powell River Division) Strait of Georgia Coastal	A	NA	NA	NA	NA	NA
11. Northwood Pulp & Timber (Prince George) Fraser River Downstream	A	0.31	8.0	36.0	56.0	0.0
	B	12.0	5.7	60.9	33.2	0.2
	C	6.8	5.0	34.8	60.2	0.0
	D	6.4	5.5	38.5	55.9	0.0
12/13 Canfor Pulp and Intercontinental Pulp (Prince George) Upstream	A	0.52	8.1	46.7	45.2	0.0
	B	0.97	8.3	56.2	33.6	1.9
	C	0.87	37.2	54.8	5.8	2.2
Canfor Pulp and Intercontinental Pulp (Prince George) Fraser River Downstream	D	0.31	8.0	36.0	56.0	0.0
	E	0.42	5.8	40.4	53.6	0.2
	F	0.47	5.2	27.0	67.3	0.5
	G	0.15	4.0	9.1	86.9	0.0

(4) Analysis were performed on a small sample size: representativeness of the results are not ascertained.

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
14. Skeena Cellulose (Prince Rupert) Hecate Strait Coastal	A	1.96	41.8	55.7	2.5	0.0
	B	1.61	36.8	61.2	2.0	0.0
15. Cariboo Pulp & Paper (Quesnel) Fraser River Downstream	A	NA	NA	NA	NA	NA
	B	0.58	9.2	46.5	44.0	0.3
	C	0.76	9.7	42.3	47.2	0.8
	D	0.67	10.8	28.3	59.5	1.4
16. Crestbrook Forest Ind. (Pulp Division) Kootenay River Upstream	A	5.4	6.2	27.9	65.9	0.0
	B	4.7	5.4	21.4	73.2	0.0
Crestbrook Forest Ind. (Pulp Division) Kootenay River Downstream	C	13.0	8.5	54.0	37.5	0.0
	D	4.2	5.9	20.9	73.2	0.0
	E	4.2	2.0	34.7	63.3	0.0
	F	4.2	12.4	28.2	59.4	0.0
17. Western Pulp Partnership (Woodfiber) Howe Sound Coastal	A	NA	NA	NA	NA	NA
	B(4)	4.46	10	67	23	0
	C	1.26	29	68	3	0

4) Analyses were performed on a small sample size: representativeness of the results are not ascertain

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
18. Finlay Forest Industries (MacKenzie) Williston Lake Downstream	A	24.0	1.5	5.8	92.7	0.0
	B	16.7	7.4	21.0	76.6	0.0
	C	5.9	30.3	66.7	3.0	0.0
19. Quesnel River Pulp Fraser River Upstream	A	0.22	7.5	33.2	57.9	1.4
	B	0.17	5.3	26.0	68.7	0.0
	C	0.15	12.0	14.3	46.5	27.2
Quesnel River Pulp Fraser River Downstream	D	2.4	7.5	33.5	49.2	9.8
	E	0.22	3.4	5.8	89.9	0.9
	F	2.5	11.4	61.7	26.6	0.3
20. Celgar Pulp (Power Consolidated) Arrow Lake Upstream	A	0.29	-	4.1*	95.0	0.9
	B	0.14	-	3.3*	95.2	1.5
	C	0.92	6.7	39.2	52.5	1.6
Celgar Pulp (Power Consolidated) Columbia River Downstream	D	21.0	3.2	37.3	59.5	0.0
	E	4.7	5.4	55.0	39.6	0.0
	F	1.1	3.8	37.2	58.9	0.1
21. Proctor & Gamble Pulp (Grande Prairie) Wapiti River Upstream	A	1.24	24	43	33	0.0
	(AA)[3]	1.17	24	43	33	0.0
Proctor & Gamble Pulp Wapiti River Downstream	B	2.08	8	27	65	0.0
	(BB)[3]	1.72	10	23	67	0.0

* refers to % particle size of silt and clay combined
(3) replicate sample

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
22. Weldwood of Canada (Hinton) Athabasca River Upstream	A	0.75	8.0	88.0	4.0	0.0
	(AA)[3]	0.69	8.0	88.0	4.0	0.0
Weldwood of Canada (Hinton) Athabasca River Downstream	B	5.87(5)	11.9	45.8	42.3	0.0
	(BB)[3]	4.95(5)	10.4	48.4	41.2	0.0
	C	2.04	11.0	77.0	12.0	0.0
23. Weyerhaeuser Canada (Prince Albert) North Saskatchewan River Downstream	A	2.17(5)	7.1	17.8	74.4	0.7
24. Manfor (REPAP) (The Pas) Saskatchewan River Upstream	A	NA	44.0	41.2	14.8	0.0
Manfor Saskatchewan River Downstream	B	NA	10.0	23.7	65.6	0.7
25. Domtar Inc. (Cornwall) St. Lawrence River Upstream	A	1.87	4.2	9.0	80.4	6.4
Domtar Inc. St. Lawrence River Downstream	B	2.75	4.2	4.8	8.1	2.9
	C	4.31	6.2	23.9	69.9	0.0

(5) Results for total carbon (inorganic carbon included)

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
26. Canadian Pacific Forest Products (Dryden) Wabigoon Lake Upstream	A	6.93	2.00	43.0	36.0	0.0
Canadian Pacific Forest (Dryden) Wabigoon River Downstream	B	3.54	25.0	65.0	10.0	0.0
	C	4.8	41.0	54.0	5.0	0.0
	D	7.52(5)	10.0	7.0	83.0	0.0
	E	17.19(5)	<0.01	3.3	96.7**	-
27. E.B. Eddy Forest Products (Espanola) Spanish River Upstream	A	1.91	9.3	28.0	61.7	1.0
E.B. Eddy Forest Products Spanish River Downstream	B	0.34	0.0	0.8	40.8	58.6
	C	0.57	0.0	0.2	40.6	59.0
28. Boise Cascade Canada	A,B,C,D,E,F	NA	NA	NA	NA	NA
29. James River Marathon Lake Superior Downstream	A	0.14	0.0	4.0	26.0	0.0
	B	0.06	0.0	1.0	99.0	0.0
	C	0.07	0.0	1.0	99.0	0.0
	D	0.04	0.0	1.0	99.0	0.0
	E	1.54	11.0	32.0	57.0	0.0
	F	1.0	0.0	23.0	77.0	0.0

NA no analysis

(5) results for total carbon (inorganic included)

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
30. Domtar (Container Board Division) Red Rock Superior Lake Downstream	A	3.26	27.0	63.6	9.4	0.0
Domtar (Container Board Division) Red Rock Superior Lake Downstream	A	10.0	6.0	70.0	24.0	0.0
	B	13.4	5.0	60.0	35.0	0.0
	C	25.7	3.0	57.0	40.0	0.0
	E	3.14	50.0	48.5	1.2	0.3
	F	7.72	15.2	48.0	36.8	0.0
31. Fraser Inc. (Thorold) Downstream	A	7.17	0.0	1.6	95.4	3.0
32. Kimberly Clark (Terrace Bay Division) Superior Lake Downstream	A	0.25 (5)	0.0	4.0	93.9	3.0
	B	32.96 (5)	0.0	37.0	63.0	0.0
	C	11.3	7.0	41.0	52.0	0.0
33. C.P. Forest Products (Thunder bay Div.) Kaministiquia River Upstream	A	1.41	13.1	55.2	31.7	0.0
C.P Forest Products Kaministiquia River Downstream	B	1.50	5.8	22.0	63.5	8.7
	C	3.28	10.0	85.4	4.6	0.0

(5) results for total carbon (inorganic carbon included)

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
34. Malette Kraft Pulp & Power (Smooth Rock Falls) Mattagami River Upstream	A	5.24	29.0	56.6	14.4	0.0
Malette Kraft Pulp & Power (Smooth Rock Falls) Mattagami River Downstream	B	2.10	14.5	6.8	72.7	6.0
	C	0.84	5.5	12.2	63.6	18.7
35. Tembec Inc. Ottawa River Downstream	A	3.75	1.0	11.0	88.0	0.0
36. Cascades (Jonquière) Saguenay River Downstream	A	1.22	10.0	47.0	43.0	0.0
37. Les Produits Forestiers Canadien Pacifique Ltée (La Tuque) St-Maurice River Downstream	A	3.67	1.0	42.0	57.0	0.0
38. Produits des Pâtes et Papiers Domtar (Lebel-sur-Quévillon) Quévillon River Downstream		3.81	41.0	43.0	16.0	0.0
39. Stone Consolidated Inc. (Divison Pontiac) Portage-du-Fort Ottawa River Downstream	A	4.12	20.0	64.0	16.0	0.0

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
40. Donohue St-Félicien Inc. (St-Félicien) Mistassini River Downstream	A	2.76	3.0	49.0	48.0	0.0
	AA	2.56	7.0	45.0	48.0	0.0
	AAA	2.85	7.1	36.9	55.8	0.2
41. Industries James MacLaren Inc. (Thurso) Ottawa River Downstream	A	3.77	11.0	5.0	84.0	0.0
42. Stone Consolidated Inc. (Trois Rivières) Saint-Maurice River Upstream	A	1.5	0.04	44.5	55.0	0.0
Stone Consolidated Inc. Saint-Maurice River Downstream	B	0.04	0.0	0.2	97.9	1.9
	C	0.03	0.0	0.1	100.0	0.0
	D	0.08	-	10.7*	87.9	2.4
43. Les Papiers Fins Domtar (Windsor) Saint-François River Downstream	A	3.01	4.0	44.0	50.0	2.0
44. St. Anne-Mackawic (Mackawic) St. John River Upstream	A	2.12	10.0	67.0	23.0	0.0
	B	2.08	20.0	60.0	20.0	0.0
St. Anne-Mackawic St. John River Downstream	C	4.95	9.0	75.0	16.0	0.0
	D	5.17	22.0	58.0	17.0**	3.0

* referes to % particle size of silt and gravel combined

Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
45. Miramichi Pulp & Paper (Newcastle) Miramichi River Upstream	A	8.32	29.1	60.1	10.5	0.3
Miramichi Pulp & Paper Miramichi River Downstream	B	1.97	6.3	15.2	73.1	5.4
	C	3.05	6.0	14.0	64.0	16.0
46. Irving Pulp & Paper (St. John) St. John River Upstream	A	0.97	8.0	64.0	28.0	0.0
Irving Pulp & Paper St. John River Downstream	B	0.50	6.0	57.0	27.0	0.0
47. Atholville Pulp Restigouche River Upstream	A	1.21	9.0	18.0	73.0	0.0
Atholville Pulp Restigouche River Downstream*	B	2.50	17.0	56.7	19.5	6.8
48. Frasers Inc. (Edmundston) St. John River Upstream	A	1.30	8.0	32.4	58.0	2
Fraser Inc. St. John River Downstream	B	3.18	8.0	71.0	21.0	0.0

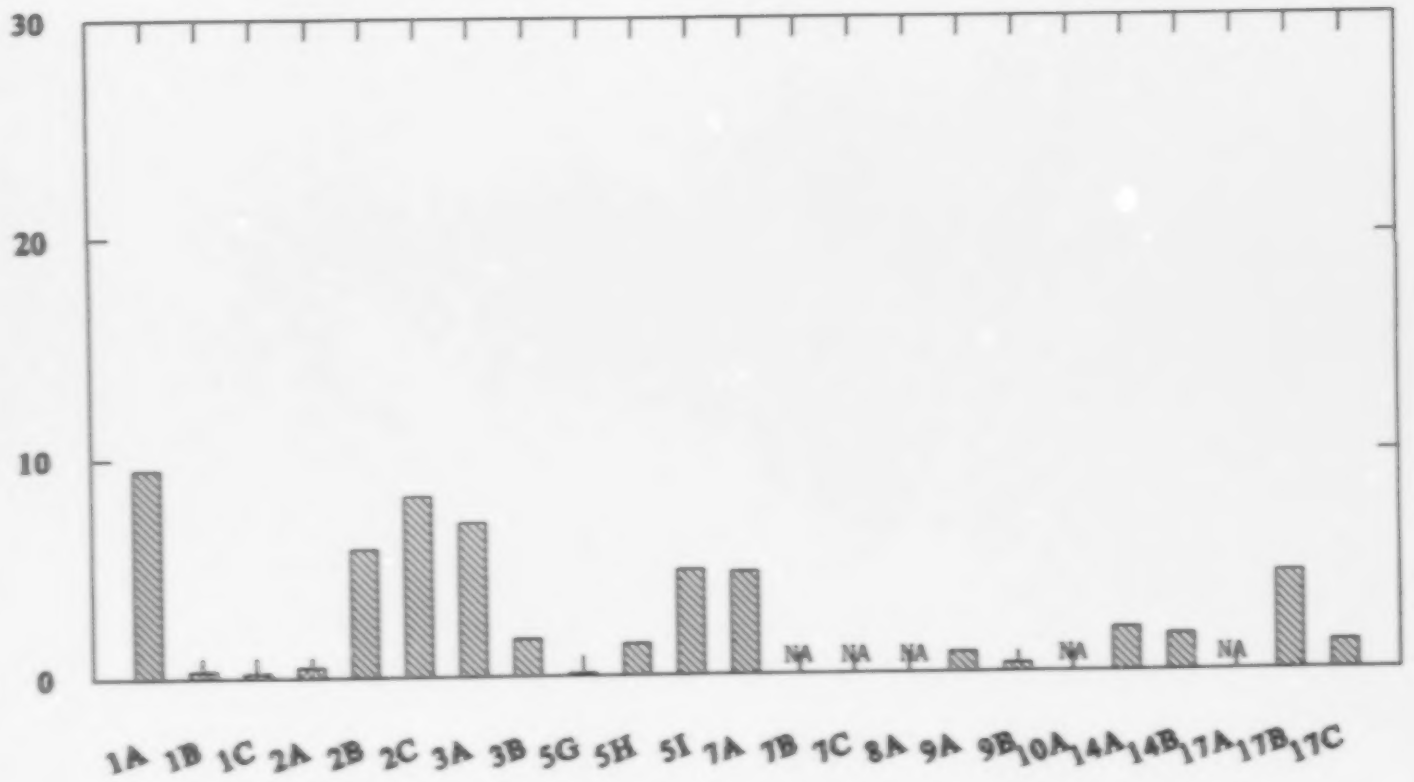
Appendix I-1. (Continued)

Sampling Location	Specific Site No. (1)	Total Organic Carbon (% by weight)	PARTICLE SIZE DISTRIBUTION (2)			
			% Clay	% Silt	% Sand	% Gravel
49. Scott Maritimes (New Glasgow) Northumberland Strait Coastal	A	0.15	0.0	3.0	97.0	0.0
	B	0.16	0.0	3.0	97.0	0.0
50. Stora Forest Products (Port Hawkesbury) Strait of Canso Coastal	A	4.43	NA	NA	NA	NA
	B	8.56	2.0	24.0	74.0	0.0
51. Western Pulp Partnership (Port Alice) Coastal	A	NA	NA	NA	NA	NA
	B	NA	NA	NA	NA	NA

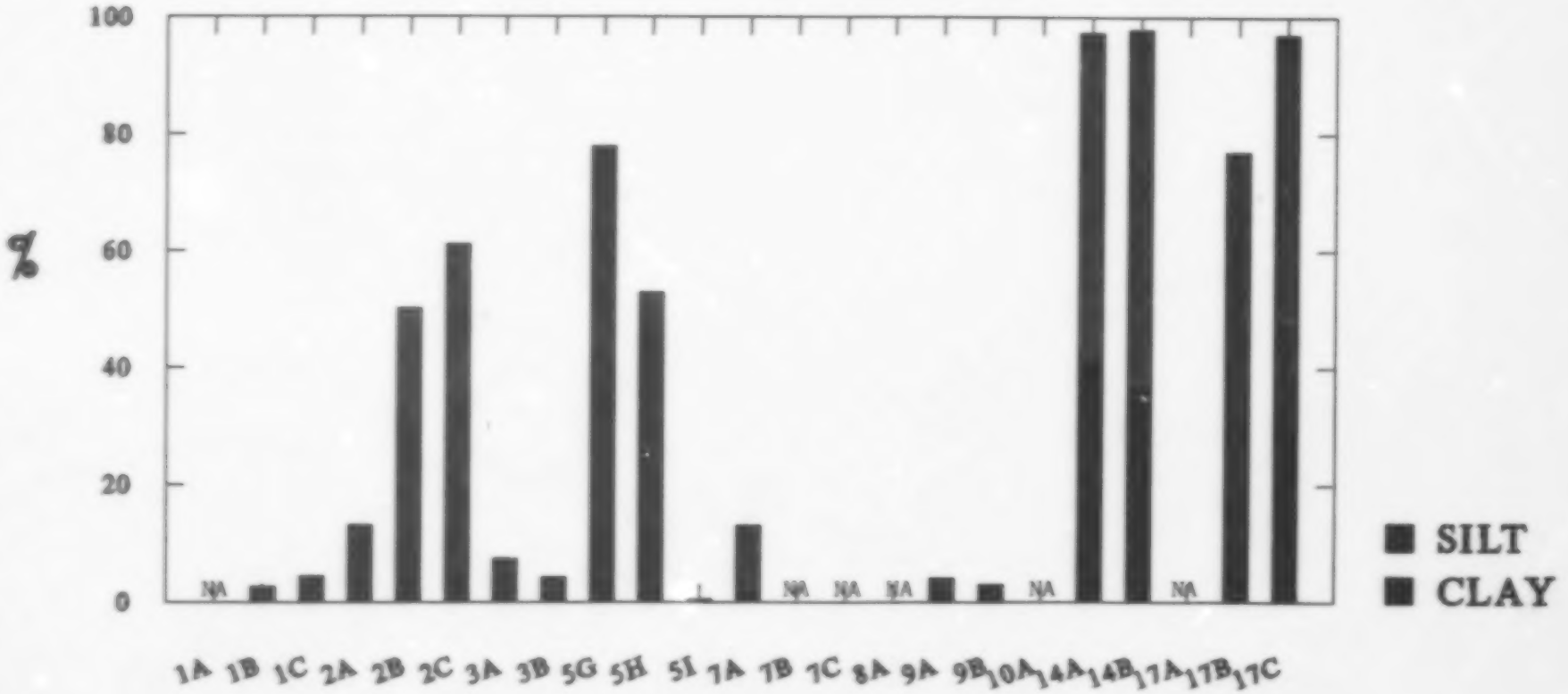
APPENDIX I-2

GRAPHS OF PARTICLE SIZE DISTRIBUTION (PROPORTION OF CLAY AND SILT) AND ORGANIC CARBON CONTENT IN SEDIMENTS COLLECTED IN BRITISH COLUMBIA (COASTAL), BRITISH COLUMBIA (INLAND), PRAIRIES, ONTARIO, QUEBEC AND ATLANTIC PROVINCES

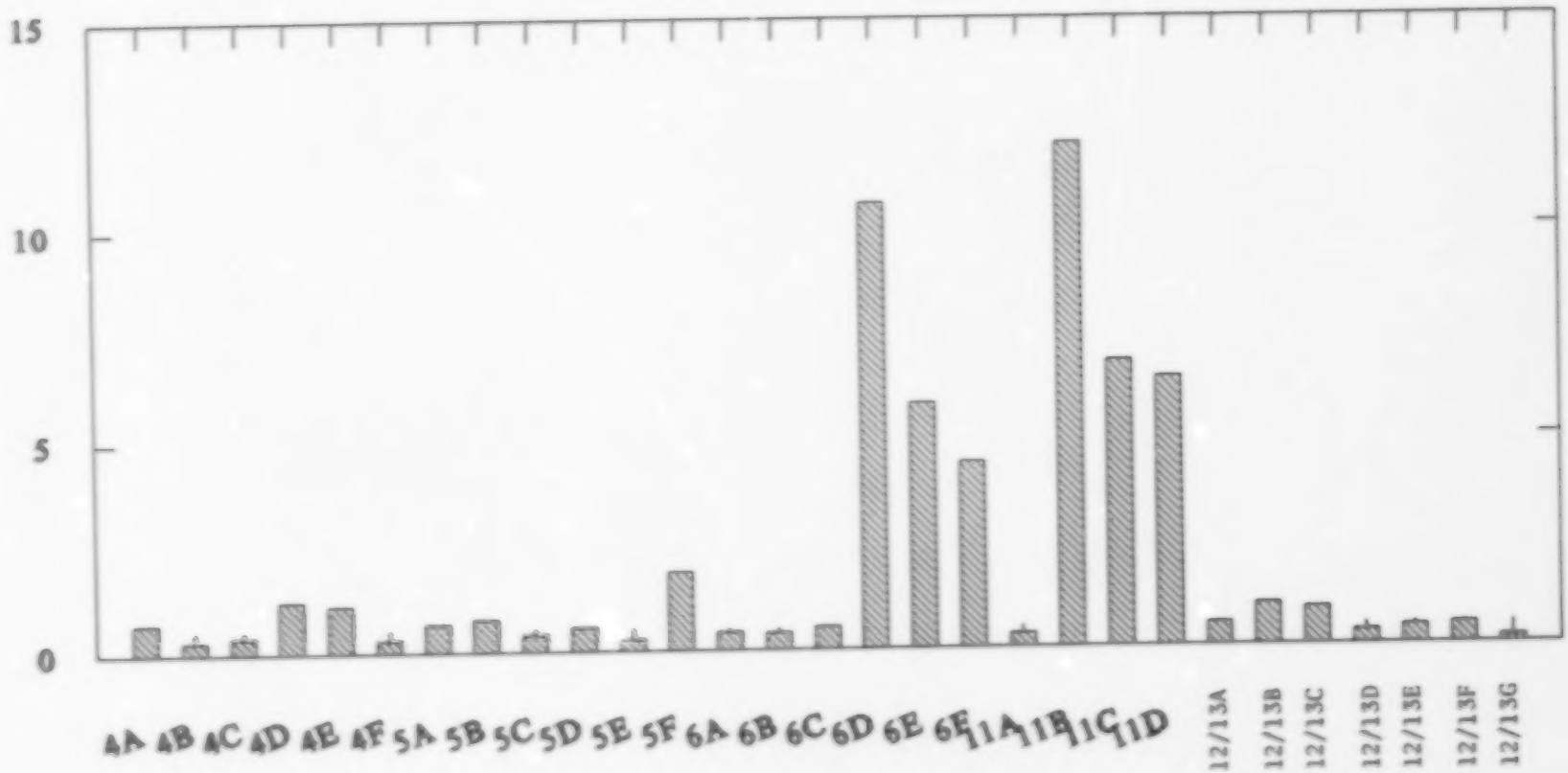
Organic Carbon Content (%) – British Columbia Coastal Sites



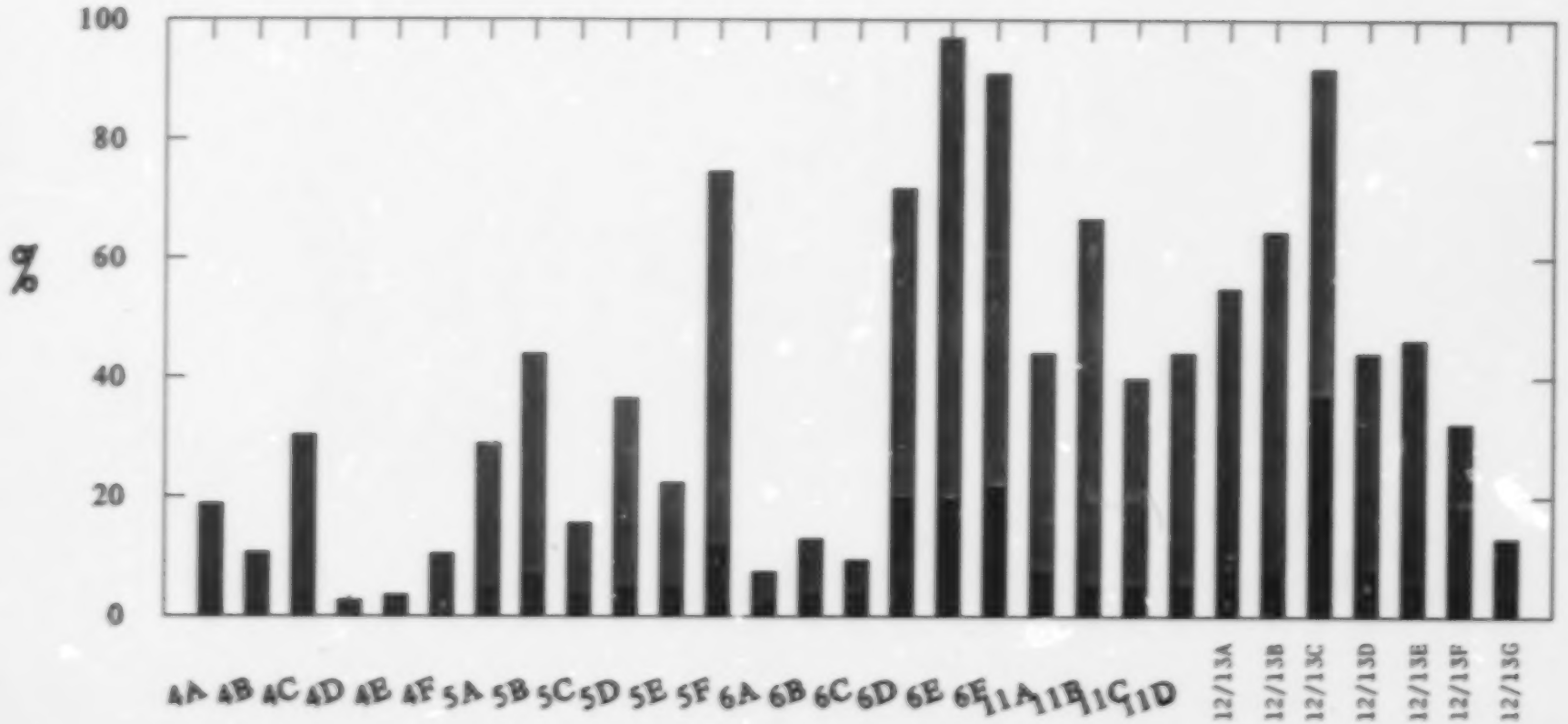
Particle Size Distribution – British Columbia Coastal Sites



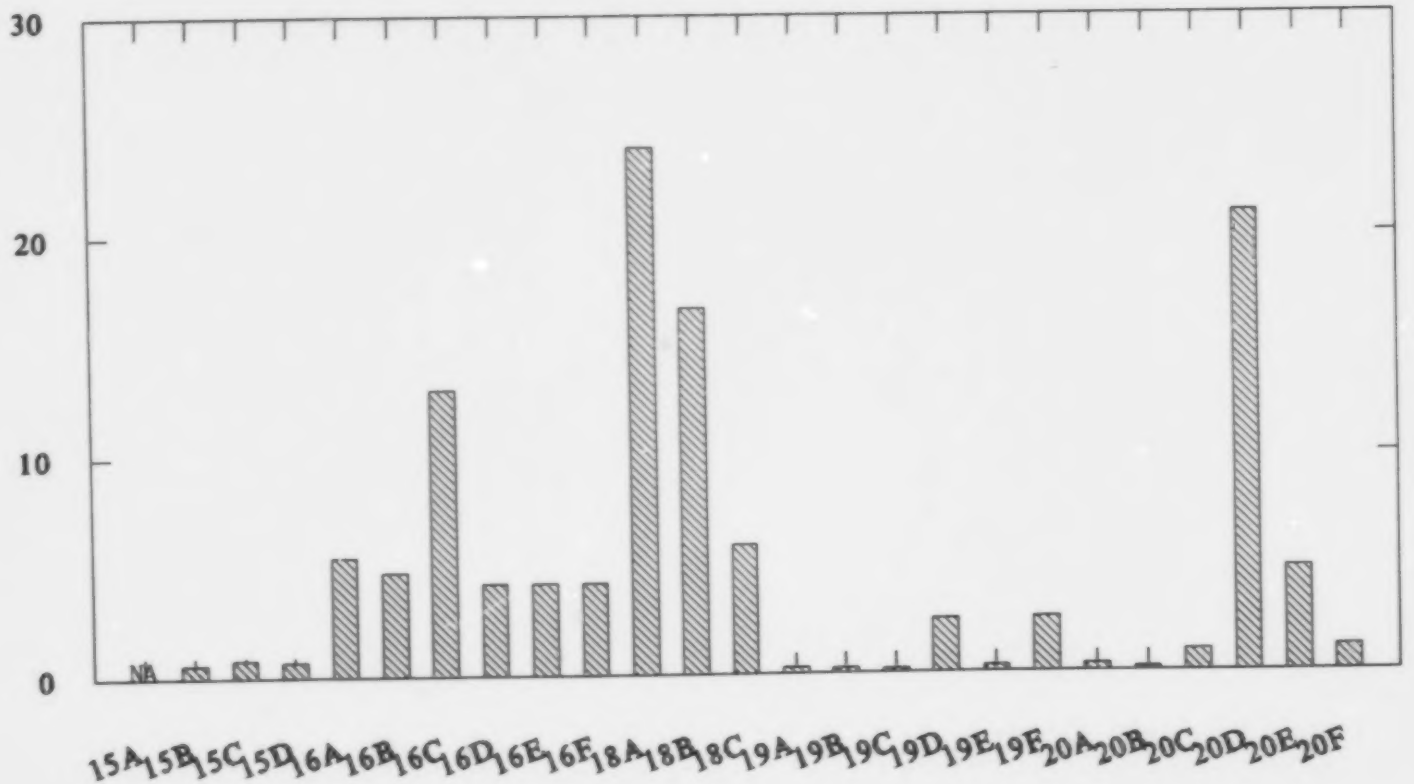
Organic Carbon Content (%) – British Columbia Sites



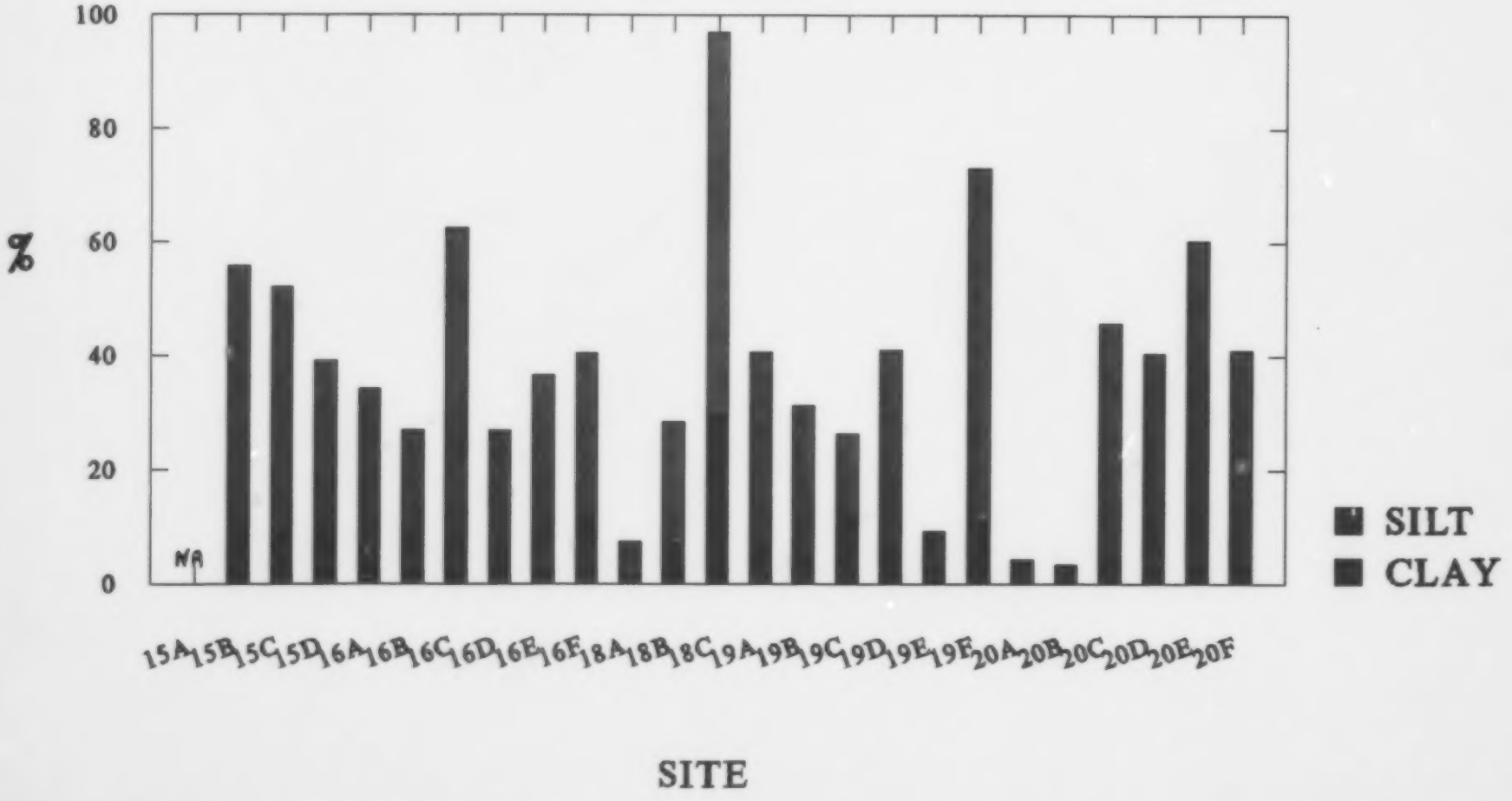
Particle Size Distribution – British Columbia Sites



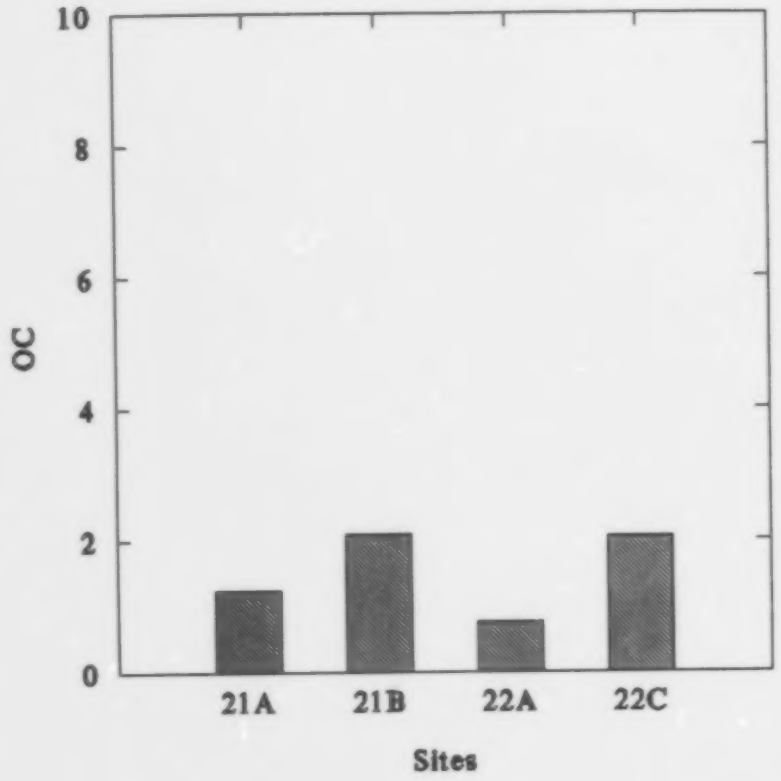
Organic Carbon Content (%) – British Columbia Sites



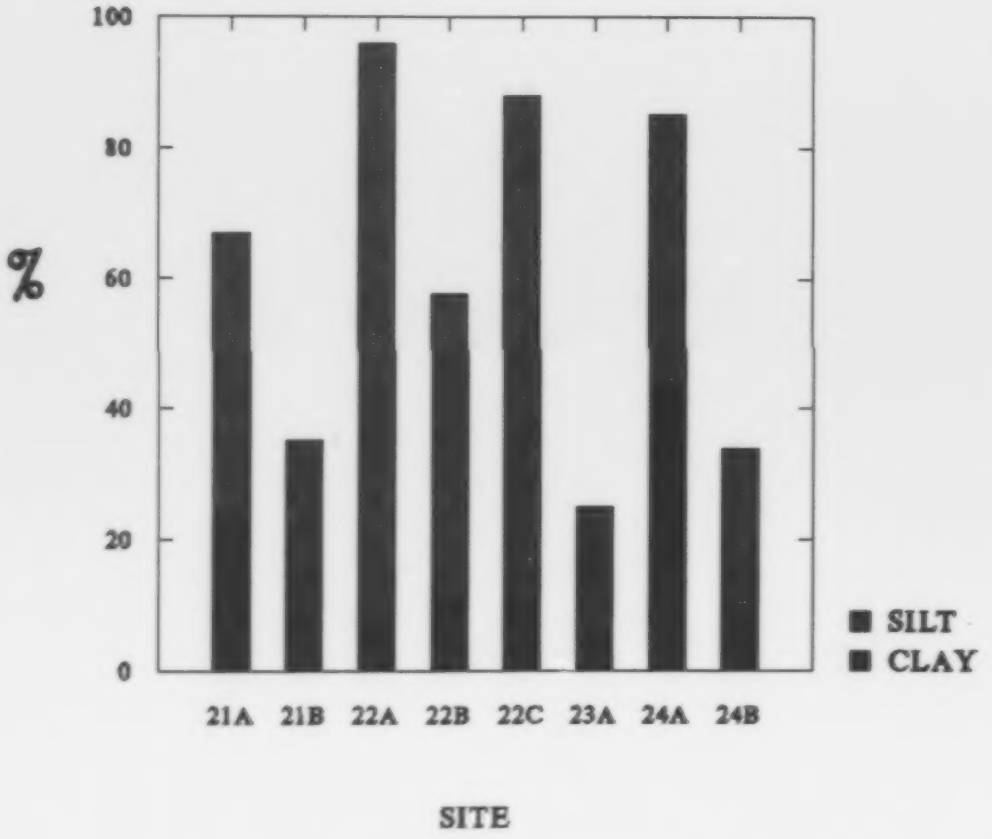
Particle Size Distribution – British Columbia Sites



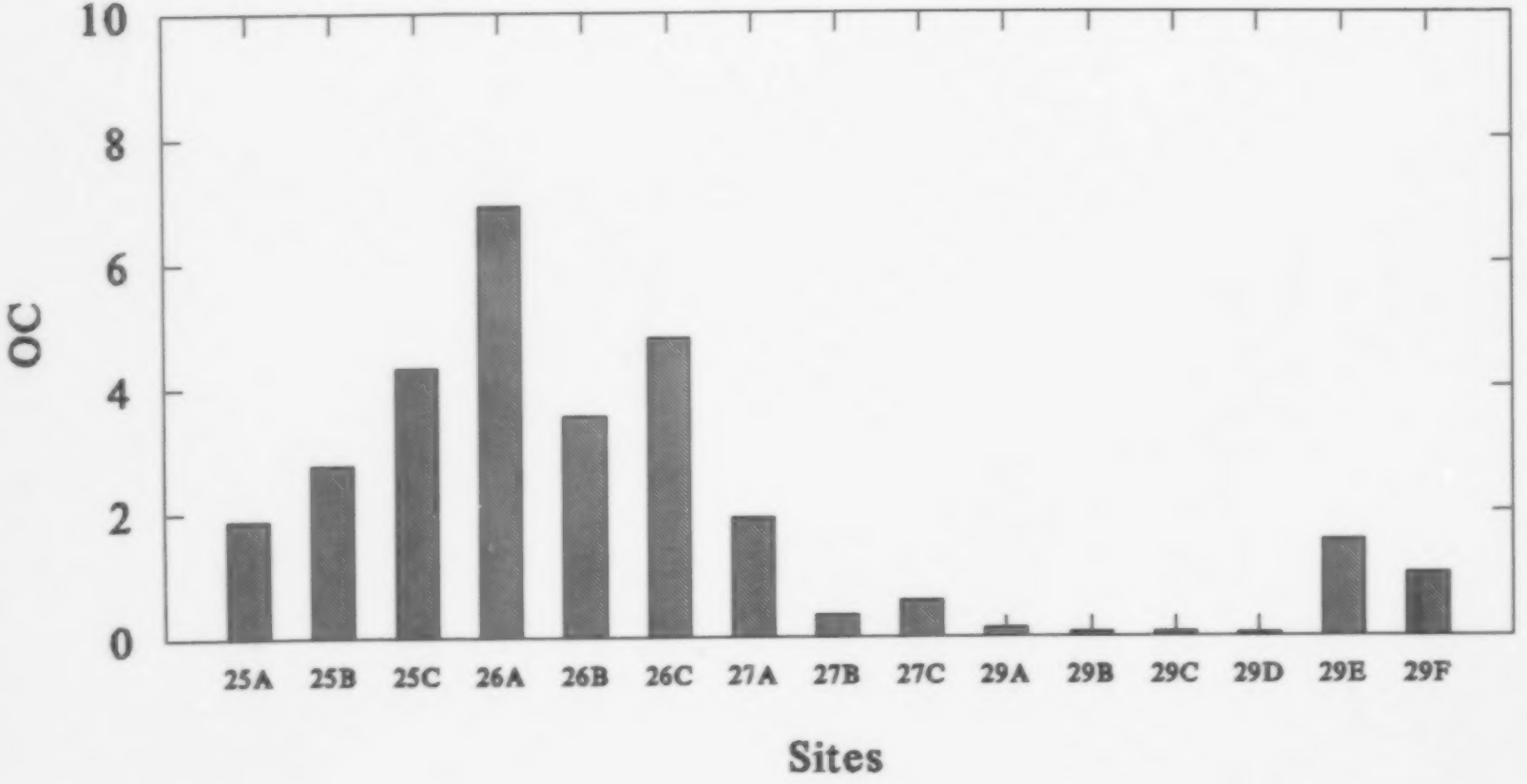
Organic Carbon Content (%) – Prairie Sites



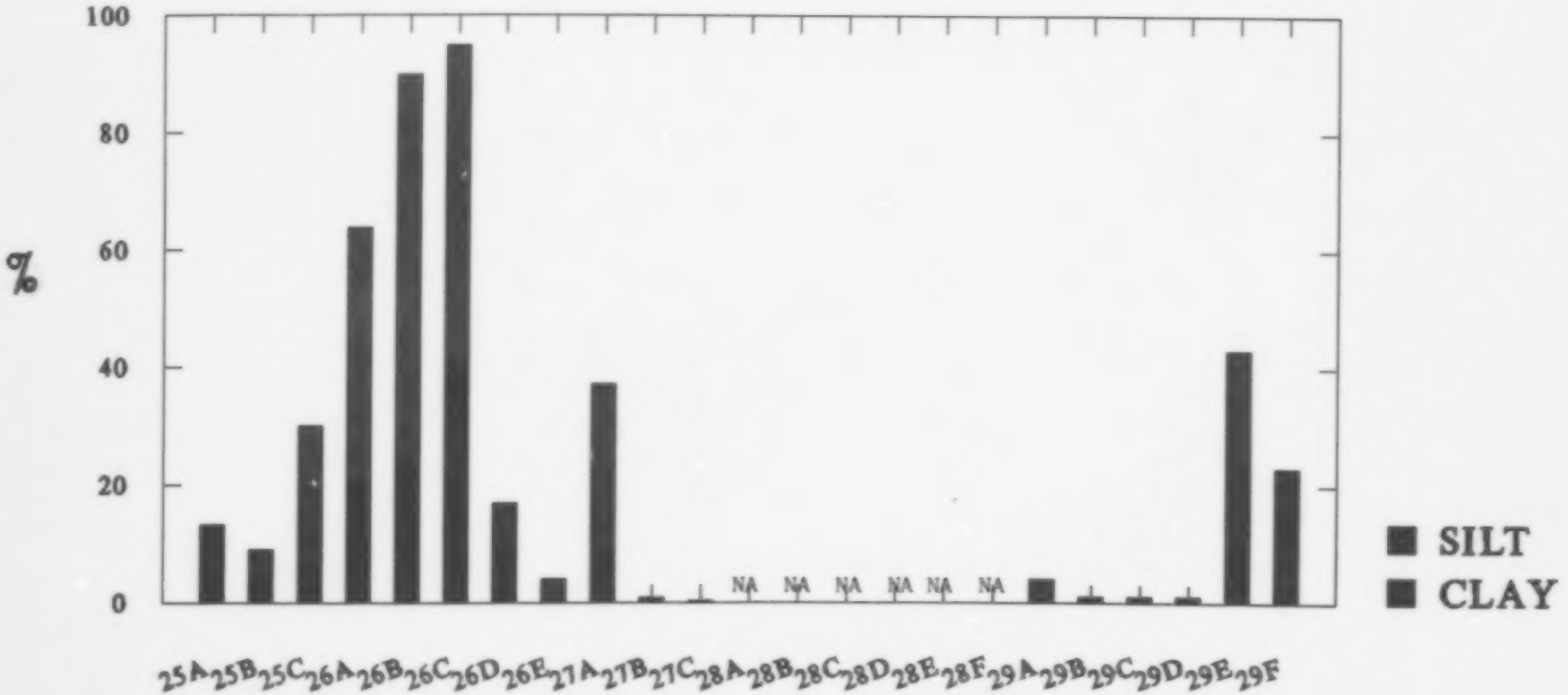
Particle Size Distribution – Prairie Sites



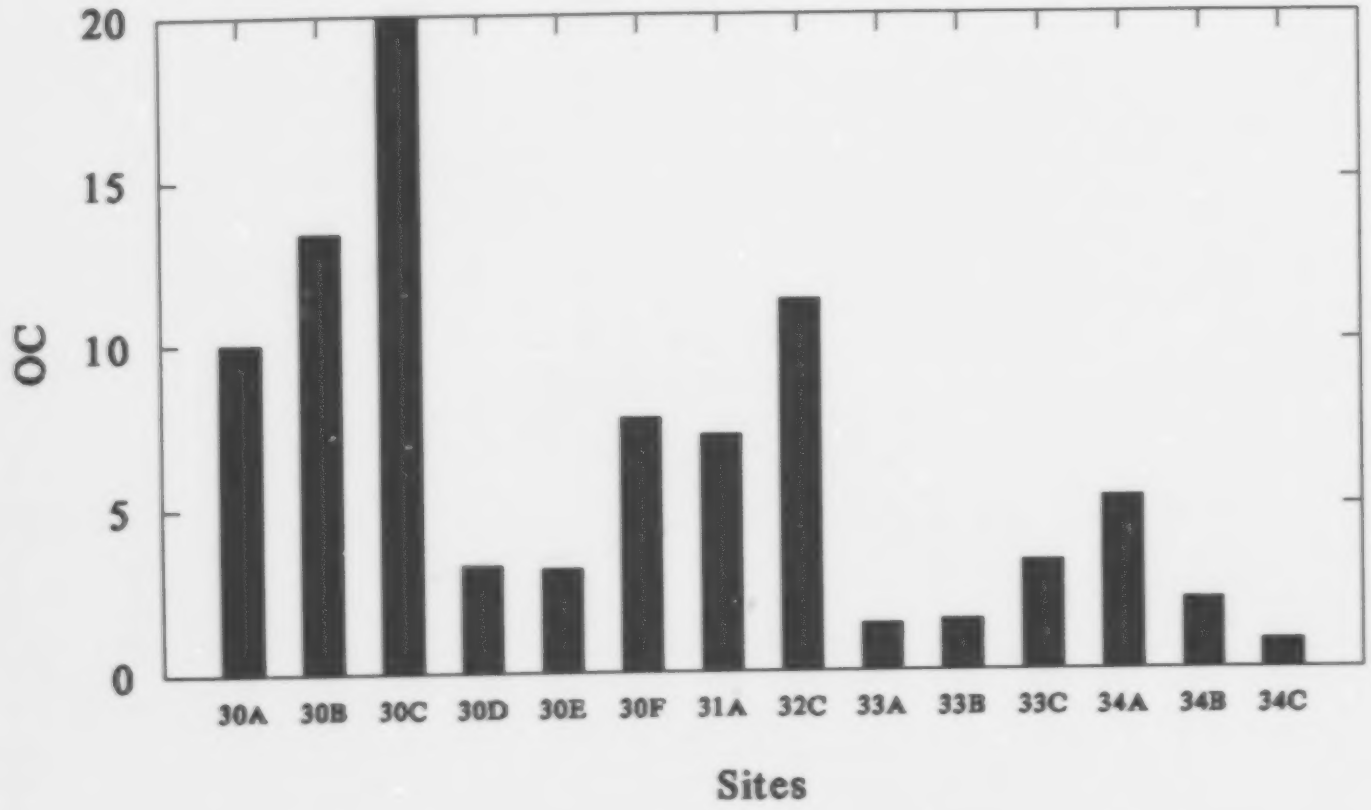
Organic Carbon Content (%) – Ontario Sites



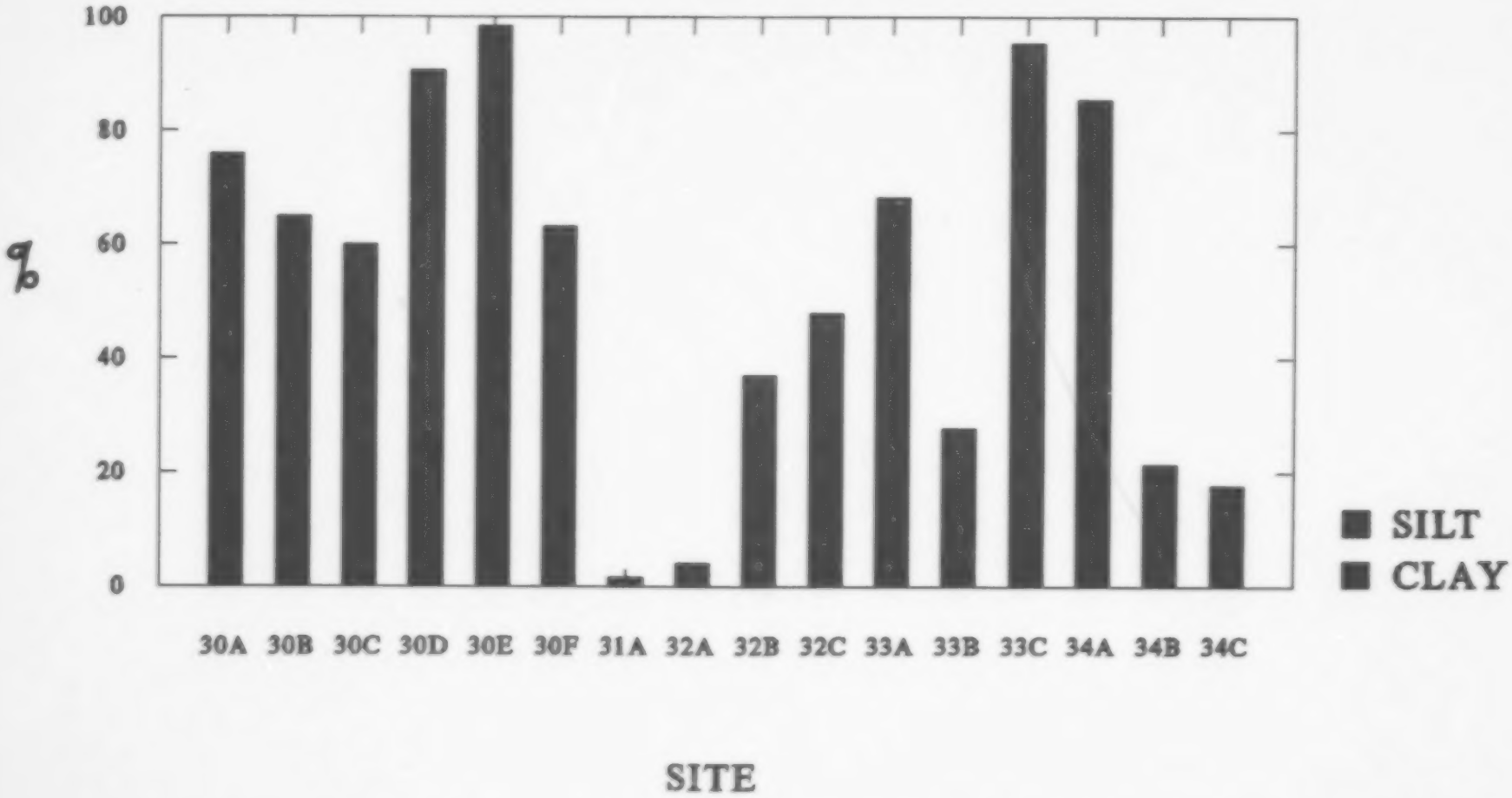
Particle Size Distribution – Ontario Sites



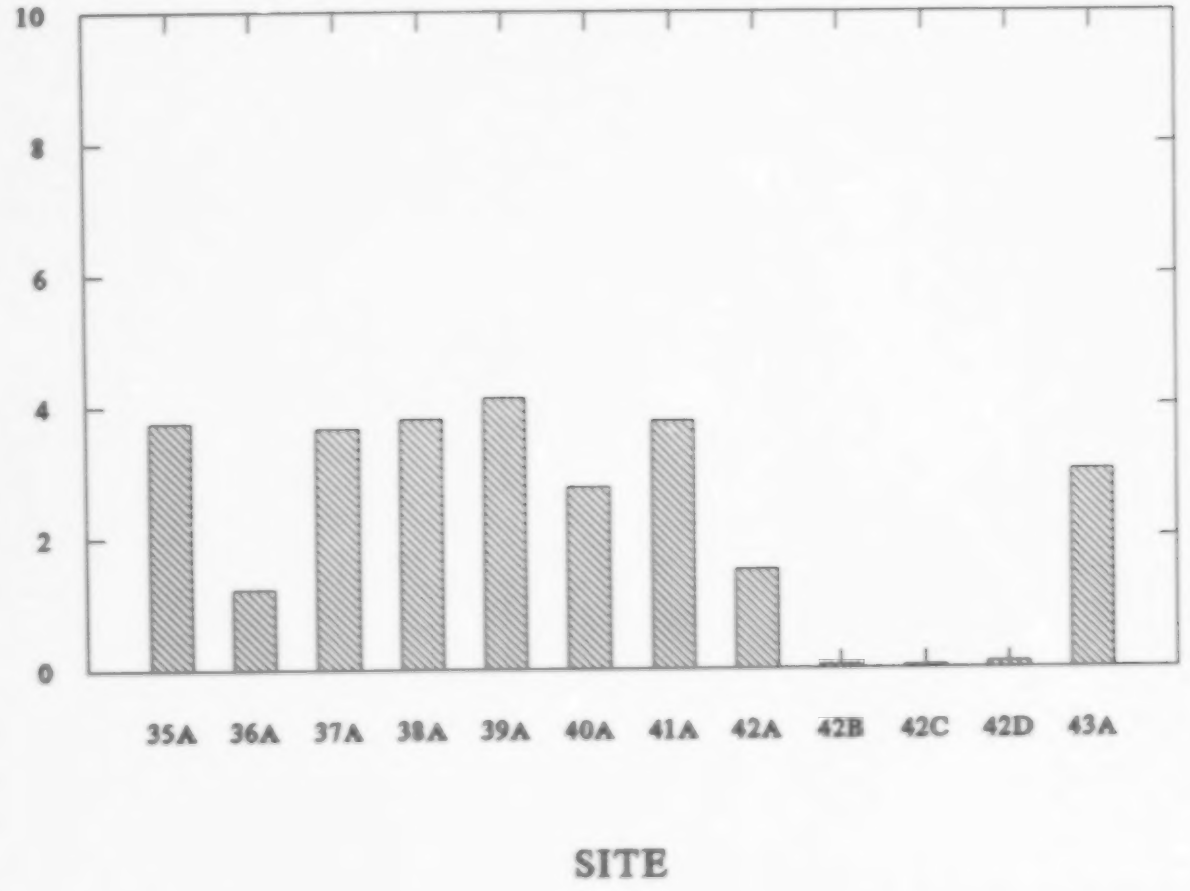
Organic Carbon Content (%) – Ontario Sites



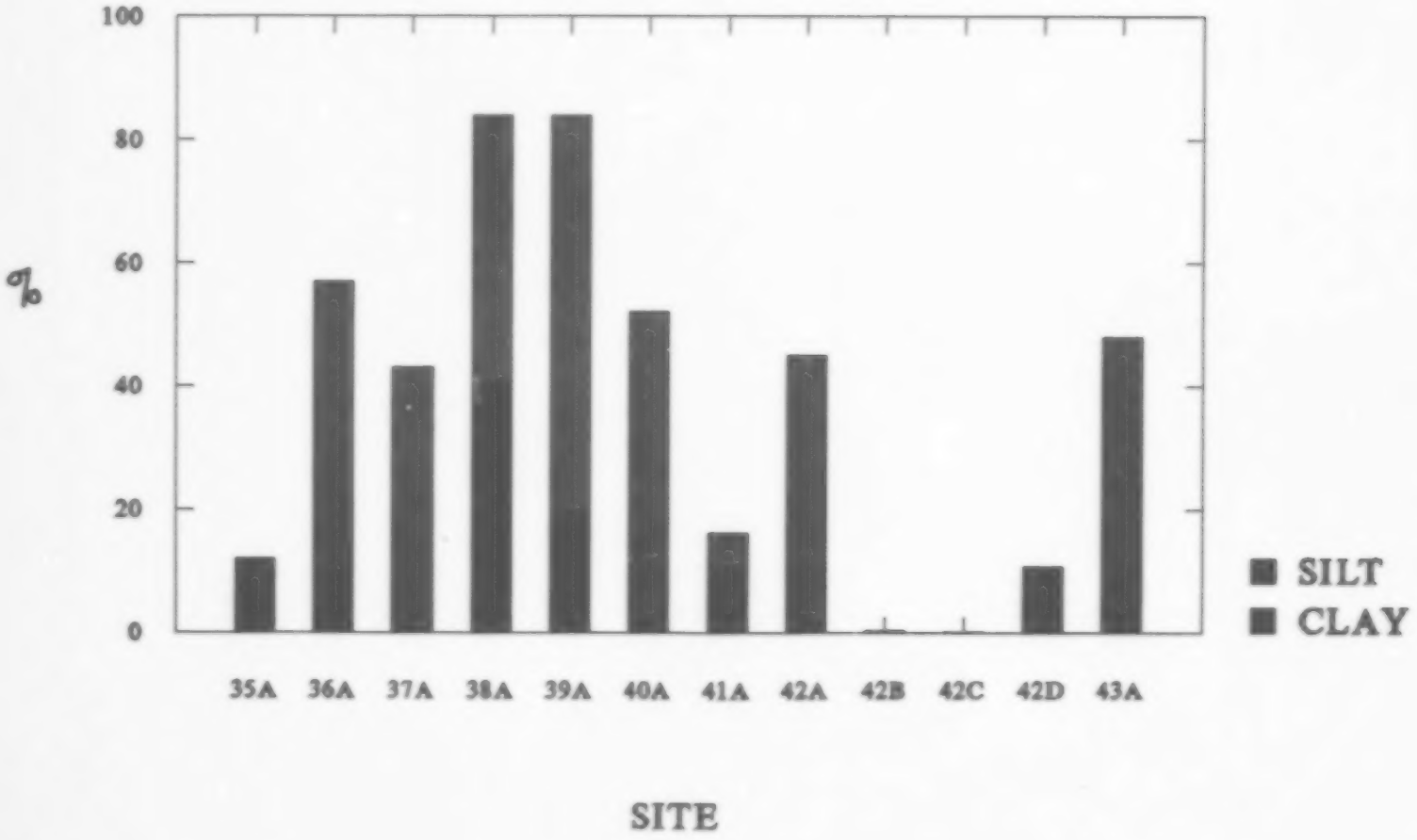
Particle Size Distribution – Ontario Sites



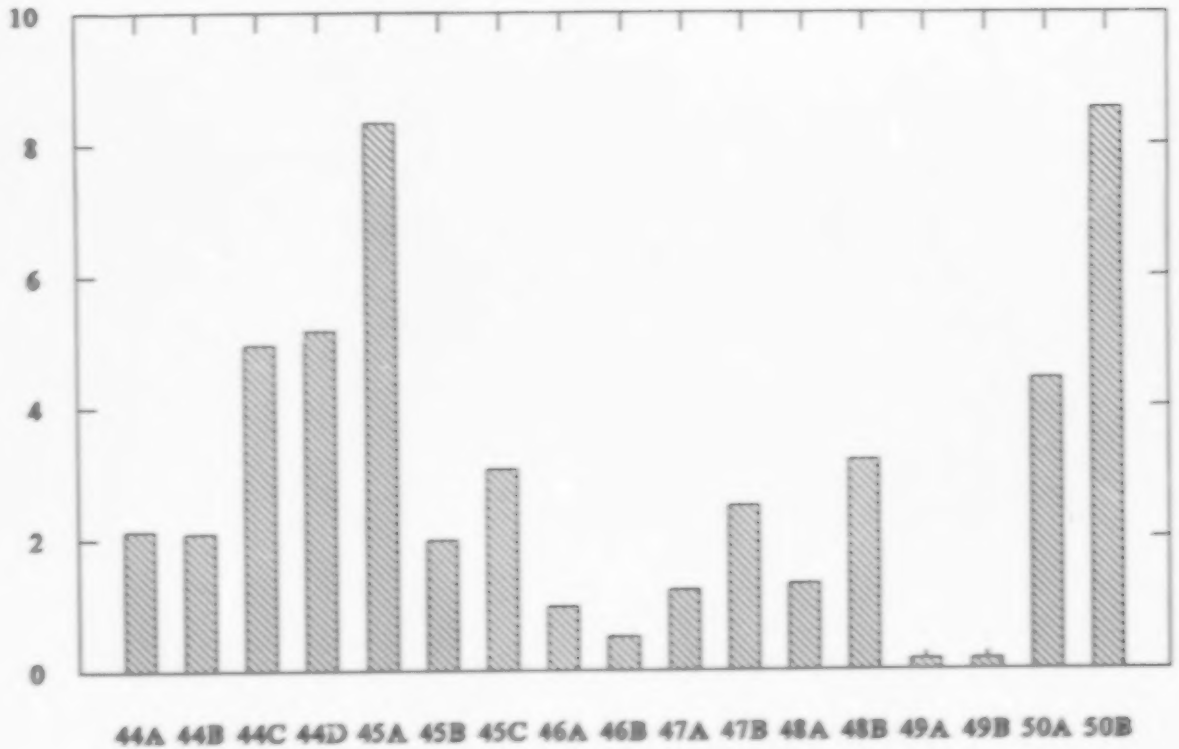
Organic Carbon Content (%) – Quebec Sites



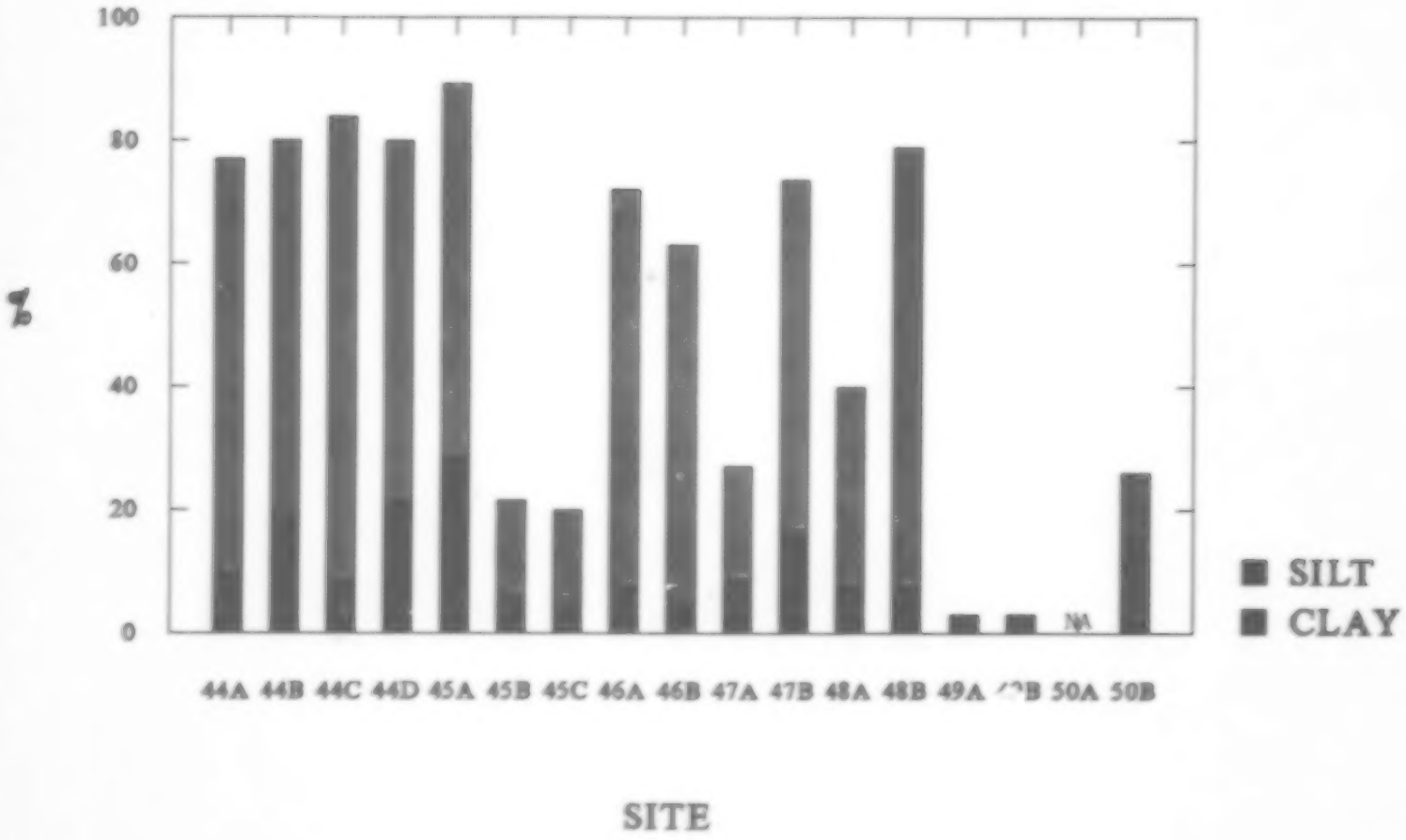
Particle Size Distribution – Quebec Sites



Organic Carbon Content (%) – Atlantic Sites



Particle Size Distribution – Atlantic Sites

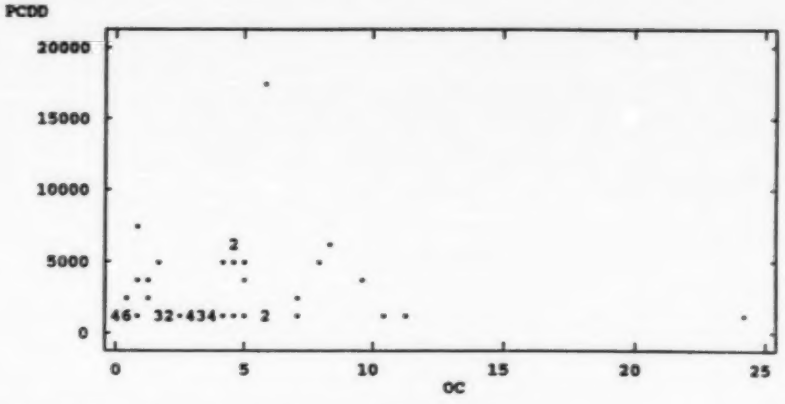


APPENDIX I-3

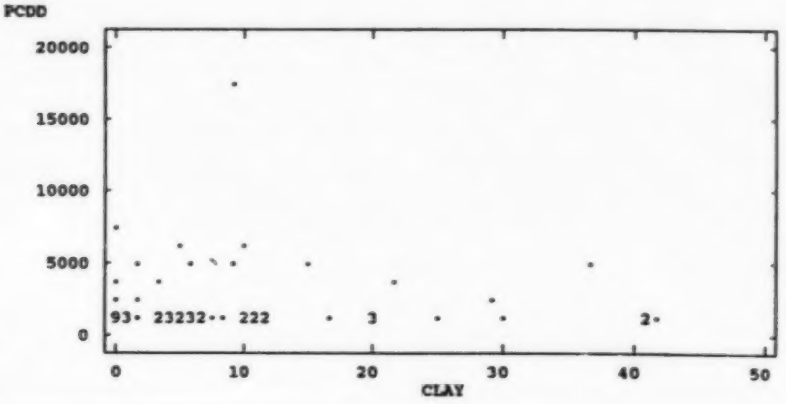
RELATIONSHIP BETWEEN PCDD/PCDF CONCENTRATIOS AND SEDIMENT CHARACTERISTICS (PERCENT OF CLAY, FINE AND ORGANIC CARBON CONTENT) AT COASTAL AND DOWNSTREAM INLAND SITES

APPENDIX I-3

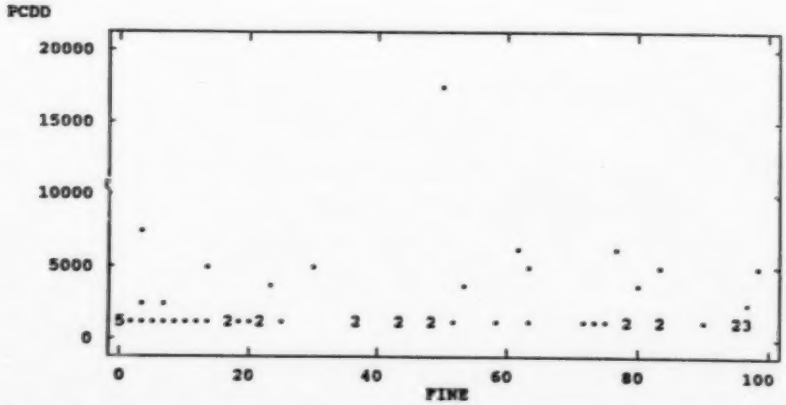
RELATIONSHIP BETWEEN PCDD CONCENTRATIONS AND SEDIMENT CHARACTERISTICS COASTAL AND DOWNSTREAM INLAND SITES



61 CASES WITH MISSING VALUES EXCLUDED FROM PLOT



58 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

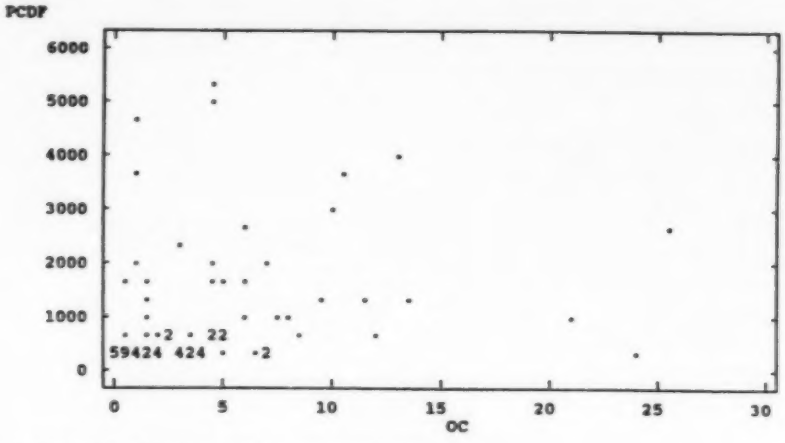


58 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

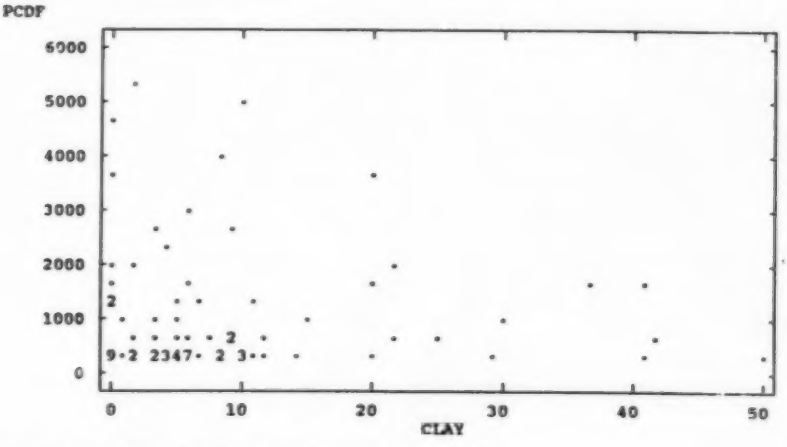
* Concentration below detection limits are treated as missing values

APPENDIX I-3

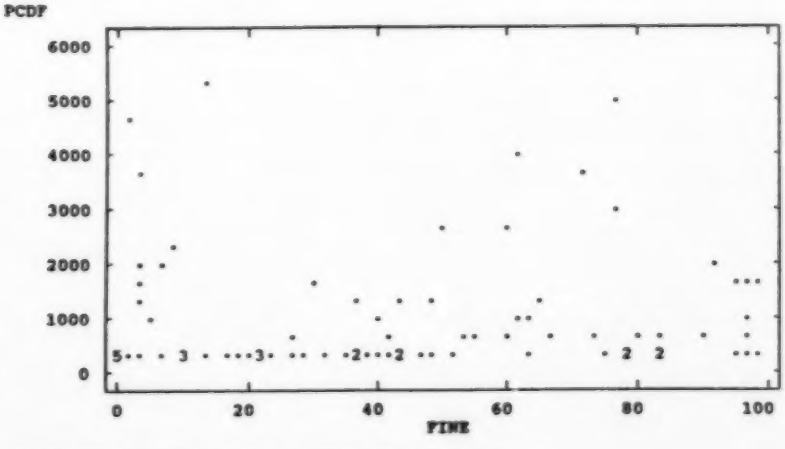
RELATIONSHIP BETWEEN PCDF CONCENTRATIONS AND SEDIMENT CHARACTERISTICS COASTAL AND DOWNSTREAM INLAND SITES



36 CASES WITH MISSING VALUES EXCLUDED FROM PLOT



34 CASES WITH MISSING VALUES EXCLUDED FROM PLOT



34 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

* Concentration below detection limits are treated as missing values